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VOLUME 16 JANUARY, 1942 NUMBER 1

CENOZOIC IRREGULAR ECHINOIDS OF EASTERN UNITED STATES

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ABSTRACT—This paper treats of 115 species referred to 46 genera or subgenera representing 11 families. Twenty-one species are described as new. One new generic name, *Echanthus*, replaces *Echinanthus* of authors, not Leske, 1778. Two new family names, Echinocyamidae and Echinocardiidae, are proposed. The nomenclature is thoroughly revised, and genotypes are designated for all genera. Transfers involve many genera.

The Paleocene epoch is represented by 3 species, the early Eocene by 7, the middle Eocene by 6, the late Eocene by 52, the Oligocene by 12, the Miocene by 8, the Pliocene by 11 (3 still living), the Pleistocene by 5 (all living), and the Recent by 13.

THIS PAPER, a companion to the one on regular echinoids published in volume 15 of this Journal (pp. 1–20, pls. 1–4, January 1941), completes the study of the Cenozoic echinoids of the Atlantic and Gulf Coastal Plain of the United States. Like the other, it is based primarily on collections in the United States National Museum, though collections of the Florida Geological Survey, the Geological Survey of Alabama, and the Johns Hopkins University have been studied. Most of the extinct species not figured here are illustrated in W. B. Clark and M. W. Twitchell's (1915) "Mesozoic and Cenozoic Echinodermata of the United States" (U. S. Geol. Survey Mon. 54), which can still be purchased from the Superintendent of Documents, Washington, D. C. Excellent figures of most of the Recent species will be found in Alexander Agassiz's (1872–1874) "Revision of the Echini."

The use of Cenozoic echinoids for correlation has been greatly hampered by the lack of accurate published data on their stratigraphic ranges. Since the manuscript of Clark and Twitchell's monograph was completed, the stratigraphic column as known to them has undergone drastic revision. The Vincentown sand of New Jersey, then supposed to be Upper Cretaceous, has proved to be early Eocene. The Ocala limestone, from which many of their supposed Oligocene species were derived, has been transferred to the late Eocene. These and other changes make the references to geologic horizons in that monograph utterly unreliable and misleading. The supposed age of every species treated herein is brought up to date in the following list.

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Lovenia? sp.
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Paleocene.—Only three species are listed from the Paleocene (Midway)—*Echanthus georgiensis*, *Schizaster* (*Linthia*) *alabamensis*, and *Eupatagus?* (*Brissopatagus?*) *primus*. None of the genera suggest an age older than Tertiary. No regular echinoids are known from this unit in the eastern United States.

Early Eocene.—The formations of early Eocene age that contain echinoids are the Vincentown sand of New Jersey (supposed by W. B. Clark to be Upper Cretaceous), the Salt Mountain limestone of Alabama (supposed by Clark to be late Oligocene), and the Bashi formation of Alabama, from which last only *Eurhodia? elbana* has been obtained. Species of *Trematopygus*, *Hemiaster*, *Echinocorys*, and *Holaster* in the Vincentown sand are reminiscent of the Cretaceous, but the presence of a *Psammechinus* and a *Schizaster* is indicative of the Cenozoic. Seven species of irregular echinoids (six genera) are listed from the early Eocene, and there are also eight regular echinoids. Besides these, *Cassidulus* (*Galerolampas*) *fontis*, found in a deep well, may have come from this horizon or from the Paleocene.

Middle Eocene.—Six species from the Lisbon, Cook Mountain, or Mount Selman formations include a *Fibularia*, two Protoscutellas, a *Porpitella*, a *Schizaster*, and a *Hemipatagus*. Only one regular echinoid, a *Psammechinus*, has been reported from this horizon.

Late Eocene.—Echinoids were much more abundant in the North American region during late Eocene (Jackson) time than at any other part of the Cenozoic era. The list includes 52 species of irregular echinoids. Eight or nine regular echinoids have also been described. These 60 or 61 species include two different but closely related successive faunas. The older occupies the Castle Hayne marl of North Carolina, the Santee limestone of South Carolina, the lower part of the Ocala limestone of Georgia and Alabama, and the Moodys marl (including the beds formerly called "Gosport" or "Claiborne sand") of Alabama and Mississippi. The most common and widespread species of this older zone is *Periarchus lyelli*, which, with its several varieties, extends from North Carolina to Louisiana. It is the so-called *Scutella* from which the "*Scutella* bed" is named. This species occurs rarely in the succeeding zone, but it has not been found in beds older than basal Jackson.

The other late Eocene fauna is that of the Ocala limestone, which contains a profusion of *Oligopygus*, Laganidae, and *Eupatagus* and includes several West Indian species. Among the more common species are *Oligopygus haldemani*, *Peronella crustuloides*, *P. cubae*, *Cassidulus* (*Paralampas*) *conradi*, and *Schizaster armiger*.

These late Eocene faunas, though presumably less completely known than the Recent, contain three times as many species as are living today off the Atlantic and Gulf coasts of the United States. The faunas are remarkable in that many of the genera that disappeared completely from the Atlantic at the end of the Eocene are still flourishing in the Indo-Pacific region.

Oligocene.—Only 12 irregular echinoid species are listed from the Oligocene. *Cyclaster druryensis* is the only species reported from the early Oligocene (Red Bluff), to which it is restricted. Four or five occur in the middle Oligocene (Marianna, Glendon, and Byram, in succession), of which two or three persisted into late Oligocene time (Flint River, Suwannee, and Chickasawhay, contemporaneous). *Clypeaster rogersi* is the commonest species. The late Oligocene contains 5 regular and 10 irregular echinoids, of which *Cassidulus gouldii* is the most abundant in the Suwannee limestone and *Echinolampas aldrichi* in the Chickasawhay.

Miocene.—Four regular and eight irregular Miocene echinoids are known. True *Scutella* appears in the early Miocene Hawthorn formation and middle Miocene Choptank formation. Other genera represented are *Clypeaster*, *Encope*, *Echinocyamus*, *Cassidulus*, *Echinocardium*, and *Lovenia*. Regular echinoids are represented by species of *Arbacia*, *Stirechinus*, and *Psammechinus*.

Pliocene.—The Pliocene has yielded 3 regular and 11 irregular species, representing *Clypeaster, Encope, Leodia, Cassidulus, Agassizia, Brissus, Eupatagus* (*Plagiobrissus*), *Echinocardium, Arbacia,* and *Psammechinus.* At least three species are not extinct.

Quaternary.—The Recent fauna off the coast of the eastern United States includes 8 or more regular and 13 irregular species, of which 1 regular and 5 irregular species have been found in the late Pleistocene Pamlico or Anastasia formations or in the contemporaneous Miami oolite.

DIAGNOSTIC FEATURES

The irregular echinoids are those in which the periproct (the opening in the test through which the anus protrudes) lies outside of the apical system (a group of plates containing the ocular and genital pores and the madreporite, and from which the ambulacral and interambulacral areas radiate). They are conspicuously bilaterally symmetrical in form and surface structure, thus contrasting with the regular echinoids, most of which are nearly circular in form and radially symmetrical in surface structure. The peristome (the aperture containing the mouth), though always on the lower surface, may be either central, as in the regular echinoids, or farther forward. The groups of ambulacral pores near the mouth may form conspicuous phyllodes separated by swollen bourrelets, both together constituting a floscelle, or they may be very inconspicuous. In many genera the periproct is on the lower surface behind the peristome, but in others it is marginal or supramarginal. In some species its location is variable. It may be flush or sunken or, if supramarginal, sheltered by a rostrate extension of the test. The ambulacral areas may be distinctly petaloid or not. In some families the anterior, or odd, ambulacral area differs markedly from the paired areas in the arrangement of its pores. This feature is the first basis of division in the key to the families and genera.

KEY TO THE FAMILIES AND GENERA OF CENOZOIC IRREGULAR ECHINOIDS OF EASTERN UNITED STATES

1. Odd ambulacrum like the others.
2. Peristome not surrounded by a floscelle.
3. Test swollen or globular, margin conspicuously rounded ..... ECHINONEIDAE.
4. Adult less than 10 mm. long; peristome and periproct round ..... *Fibularia.*
4. Adult more than 10 mm. long.
5. Periproct basal.
6. Periproct small, round; peristome deeply sunken ..... *Oligopygus.*
6. Periproct large, pyriform; peristome asymmetrical.
7. Ambulacra petaloid or subpetaloid ..... *Amblypygus.*
7. Ambulacra not petaloid ..... *Echinoneus.*
5. Periproct terminal or above the margin, in a flattened area ..... *Trematopygus.*
3. Test shield-shaped, base flat, or concave.
4. Having ambulacral grooves leading to peristome.
5. Without buccal tubes; grooves generally straight; five genital pores ..... CLYPEASTRIDAE, *Clypeaster.*
5. Having buccal tubes; grooves generally forked ..... SCUTELLIDAE.
6. Without lunules or ambulacral notches; with or without posterior notch.
7. Outline circular or faintly fluted.
8. Five genital pores; poriferous zones wider than interporiferous zones; periproct not near the margin ..... *Periarchus.*
8. Four genital pores; poriferous zones narrower than interporiferous zones, expanding distally; periproct marginal or supramarginal ... *Echinarachnius.*
7. Outline not circular, generally notched posteriorly; periproct near the margin.
8. Five genital pores; posterior notch weak ..... *Protoscutella.*
8. Four genital pores; posterior notch stronger ..... *Scutella.*
6. Having lunules or ambulacral notches.
7. Five genital pores; outline sagittate or not ..... *Encope.*
7. Four genital pores; outline not sagittate.
8. Without lunule in anterior ambulacral area ..... *Mellita.*
8. Having lunule in anterior ambulacral area ..... *Leodia.*
4. Without ambulacral grooves or buccal tubes.
5. Ambulacral areas plainly petaloid; petals closed ..... LAGANIDAE.
6. Five genital pores ..... *Laganum.*
6. Four genital pores.

7. Lower surface flat ..... *Rumphia*.
7. Lower surface concave ..... *Peronella*.
5. Ambulacral areas not plainly petaloid; poriferous zones not closed .... ECHINOCYAMIDAE.
6. Periproct below ..... *Echinocyamus*.
6. Periproct above ..... *Porpitella*.
2. Peristome surrounded by a floscelle.
3. Periproct above the margin ..... CASSIDULIDAE.
4. Periproct wider than high; opening into a sulcus.
5. Periproct flush ..... *Cassidulus* s. l.
6. Periproct not terminal ..... *Cassidulus* (*Cassidulus*).
6. Periproct terminal.
7. Upper surface inflated; under surface not concave except near the peristome ..... *Cassidulus* (*Paralampas*).
7. Upper surface depressed; under surface more or less concave ..... *Cassidulus* (*Galerolampas*).
5. Periproct sunken ..... *Eurhodia*.
4. Periproct not wider than high.
5. Periproct higher than wide, terminal, slightly sunken in an emargination .... *Echanthus*.
5. Periproct nearly circular, not terminal, in a conical tube opening into a sulcus (Upper Cretaceous) ..... *Hardouinia*.
3. Periproct below the margin, nearly terminal, flush, obliquely truncated.
4. Apical system not longer than wide; madreporite central. ECHINOLAMPADIDAE. *Echinolampas*.
4. Apical system longer than wide; madreporite not central. ECHINOCORYTHIDAE. *Echinocorys*.
1. Odd ambulacrum unlike the others.
2. Peripetalous fasciole present, lateral fasciole present or not, no subanal or apical fascioles; apical system posterior or median; test generally high ..... HEMIASTERIDAE.
3. Petals deeply sunken; lateral fascioles present.
4. Four or two genital pores; anterior petals not roofed over ..... *Schizaster*.
5. Apical system posterior; petals less widely spreading ..... *Schizaster* (*Schizaster*).
5. Apical system central; petals more widely spreading ..... *Schizaster* (*Linthia*).
4. Two genital pores; anterior petals partly roofed over ..... *Moira*.
3. Petals less deeply sunken. Four genital pores.
4. Odd ambulacrum depressed, subpetaloid; no lateral fasciole; poriferous zones not obsolete ..... *Hemiaster*.
4. Odd ambulacrum very little depressed, not at all petaloid; lateral fasciole present; anterior poriferous zones of anterior petals more or less obsolete ..... *Agassizia*.
5. Anterior poriferous zones almost completely atrophied ..... *Agassizia* (*Agassizia*).
5. Anterior poriferous zones only partly atrophied ..... *Agassizia* (*Anisaster*).
2. Subanal fasciole generally present; apical system anterior or medial.
3. No apical fasciole ..... SPATANGIDAE.
4. Escutcheon, if present, not resembling spread wings; larger tubercles not confined within a peripetalous fasciole.
5. Peripetalous fasciole deeply indented.
6. Peripetalous fasciole complete; periproct large.
7. Poriferous zones not atrophied near apex.
8. Subanal fasciole complete; petals not deeply depressed ..... *Brissus*.
8. Subanal fasciole incomplete; petals deeply depressed ..... *Meoma*.
7. Poriferous zones generally atrophied and posterior petals close together near apex ..... *Brissopsis*.
6. Peripetalous fasciole incomplete, not crossing the odd ambulacrum; periproct small ..... *Cyclaster*.
5. Peripetalous fasciole not deeply indented, sometimes marginal, incomplete, or wanting.
6. Odd ambulacrum not deeply depressed; test high ..... *Macropneustes*.
6. Odd ambulacrum deeply depressed.
7. No large tubercles on upper surface; test high ..... *Holaster*.
7. Large tubercles on upper surface; test low ..... *Hemipatagus*.
4. Escutcheon resembling spread wings; large tubercles confined within a peripetalous fasciole ..... *Eupatagus*.
5. Plates on upper surface plainly swollen; tubercles arranged in concentric ranks along sutures ..... *Eupatagus* (*Gymnopatagus*).
5. Plates on upper surface not swollen; tubercles generally not in concentric ranks.
6. Apical system far forward; anterior end steeply sloping .... *Eupatagus* (*Brissopatagus*).
6. Apical system not far forward; anterior end less steeply sloping ..... *Eupatagus* (*Plagiobrissus*).
3. Apical fasciole present; apical system nearly medial ..... ECHINOCARDIIDAE.
4. Large spines on upper surface.

5. Large spines supported by internal processes..... *Lovenia.*
5. Large spines not supported by internal processes..... *Vasconaster.*
4. No large spines on upper surface..... *Echinocardium.*

SYSTEMATIC DESCRIPTIONS

Family ECHINONEIDAE A. Agassiz, 1881

Genus FIBULARIA Lamarck, 1816

Fibularia (part) LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 16.
Fibularia DESOR, *1858*, Synopsis des échinides fossiles, p. 220.
Fibularia A. AGASSIZ, *1873*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 506.
Fibularia POMEL, *1883*, Classification méthodique et genera des échinides, p. 73.
Echinocyamus LAMBERT, *1891*, Soc. géol. France, sér. 3, t. 19, pp. 749–752.
Fibularia COTTEAU, *1892*, Paléontologie française, Échinides éocènes, t. 2, p. 390.
Fibularia H. L. CLARK, *1911*, Annals and Mag. Nat. History, ser. 8, vol. 7, p. 605.
Fibularia H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 56.
Echinocyamus LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 287.

Genotype, *Fibularia trigona* Lamarck = *Echinocyamus craniolaris* Leske, living in the Indian Ocean and around the Philippines, designated by H. L. Clark (1911, pp. 598, 605). Lamarck assigned three species to *Fibularia*—*F. trigona*, *F. ovulum*, and *F. tarentina*. The first two, apparently synonyms of *Echinocyamus craniolaris* Leske, represent the usual conception of *Fibularia*—small tumid, egg-shaped species without internal partitions. The third is an *Echinocyamus*.

FIBULARIA VAUGHANI (Twitchell)

Echinocyamus vaughani TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 160, pl. 74, figs. 1a–d.
Echinocyamus vaughani LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 576.
Echinocyamus vaughani COOKE and MOSSOM, *1929*, Florida Geol. Survey Ann. Rept. 20, pl. 3, figs. 4a–b. (After Twitchell.)

Occurrence.—GEORGIA: Little Horseshoe Bend on Flint River 4 miles below Bainbridge (station 3380, type, T. W. Vaughan, collector).

FLORIDA: Well near Cedar Keys (station 13143, depths 115–288 feet); well at Leesburg (station 2076, L. C. Johnson, collector); 1 mile northwest of Newberry (station 6810, C. W. Cooke, collector); Suwannee River at Dowling Springs (station 7338, C. W. Cooke, collector); Oakhurst Lime Co. 2½ miles southeast of Ocala (station 11749, C. W. Cooke and Stuart Mossom, collectors); 2 miles northeast of Sumterville (station 12751, W. C. Mansfield and C. W. Mumm, collectors).

ALABAMA: Choctawhatchee River at railway bridge, Geneva (station 6757, C. W. Cooke, collector); stream on line between secs. 20 and 29, T. 4 N., R. 15 E., 6 miles west of Andalusia, Covington County (station 10014, C. W. Cooke and Julia Gardner, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 166486.

Remarks.—*Fibularia vaughani* is very variable in shape, ranging from forms even more elongated than the type to nearly spherical. The location of the periproct seems to be constant. The petals are obliterated in many individuals but vary little in those on which they are visible.

FIBULARIA TEXANA (Twitchell)

Echinocyamus texanus TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 120, pl. 57, figs. 2a–d, 1915.
Echinocyamus texanus LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, p. 576.

Occurrence.—TEXAS: Lee County (T. H. Aldrich, collector); San Augustine—Nacogdoches road 6.7 miles east of Attoyac Bayou, San Augustine County (station 15093, Julia Gardner and Alex Osanik, collectors).

Geologic horizon.—Middle Eocene, Mount Selman formation, Weches greensand member.

Type.—Johns Hopkins University, Baltimore, Md., 2002.

Genus OLIGOPYGUS de Loriol, 1887

Oligopygus DE LORIOL, *1887*, Recueil zool. suisse, t. 4, no. 3, p. 394.
Oligopygus DUNCAN, *1889*, Linnean Soc. London Jour., Zoology, vol. 23, p. 174.
Oligopygus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 166.
Oligopygus LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 387.
Oligopygus LAMBERT, *1931*, Soc. géol. France Bull., sér. 5, t. 1, p. 290.

Genotype, *Oligopygus wetherbyi* de Loriol, from the Eocene of Florida, by monotypy.

OLIGOPYGUS WETHERBYI de Loriol

Oligopygus wetherbyi DE LORIOL, *1887*, Recueil zool. suisse, ser. 1, t. 4, no. 3, p. 396, pl. 17, figs. 7–7d.

Oligopygus wetherbyi CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 166, pl. 78, figs. 2a–d, 3a–b.

Oligopygus wetherbyi COOKE and MOSSOM, *1929*, Florida Geol. Survey Ann. Rept. 20, pl. 3, figs 2a–b. (After Clark and Twitchell.)

Occurrence.—FLORIDA: Near Gainesville (type, A. G. Wetherby collector, fide de Loriol); 6 miles southwest of Gainesville (U. S. Nat. Mus. 164662, A. G. Wetherby collector); 5½ miles southwest of Gainesville (W. C. Mansfield and C. W. Mumm, collectors); Nixons, Levy County (station 355, U. S. Nat. Mus. 137878, L. C. Johnson, collector); Johnsons lime sink, Levy County (station 365, U. S. Nat. Mus. 137881, L. C. Johnson collector); Martin station, 9 miles north of Ocala (station 6808, C. W. Cooke, collector); Zuber (station 6807, C. W. Cooke, collector); Perry road 5.2 miles west of Mayo (station 14537, C. W. Cooke, collector); Suwannee River at Dowling Park (station 14538, C. W. Cooke and W. D. Havens, collectors); Kendrick, 4.8 miles north of Ocala (station 14125, W. C. Mansfield and C. W. Mumm, collectors); Ocala (station 4180, U. S. Nat. Mus. 165685, W. H. Merrill, collector); Suwannee River 2¼ miles above Branford (station 7345, C. W. Cooke, collector); quarry 6 miles southeast of Crystal River (station 14141, W. C. Mansfield and C. W. Mumm, collectors); quarry on Steinhatchee River opposite Clara (station 14541, C. W. Cooke and W. D. Havens, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Location unknown.

Remarks.—The shape of the peristome, which is described by de Loriol and by Clark and Twitchell as pentagonal, is generally somewhat irregular but is much more nearly oval than pentagonal. Full-grown individuals are subpentagonal in outline. A specimen from Kendrick (station 14125) measures 55 by 45.5 by 25 mm.

OLIGOPYGUS FLORIDANUS Twitchell

Oligopygus floridanus TWITCHELL, *1915*, U. S Geol. Survey Mon, 54, p. 169, pl. 79, figs. 1a–f.

Occurrence.—FLORIDA: Nigger Sink, 2 miles south of Gainesville (station 378b, L. C. Johnson, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 164660.

Remarks.—The type of this species is corroded in such a way as to reveal the ambulacral pores very plainly. The sides of the petals are nearly straight, and there is no constriction at the distal ends. The poriferous zones are narrower than those of *O. wetherbyi*, which occurs at the same locality. The type is the only individual referred to this species. It may be merely an aberrant variety of *O. wetherbyi*.

OLIGOPYGUS HALDEMANI (Conrad)

Discoidea haldemani CONRAD, *1850*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 40, pl. 1, fig. 12.

Oligopygus haldermani CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon., 54, p. 167, pl. 78, figs. 4a–d, 5a–d.

Oligopygus haldermani COOKE and MOSSOM, *1929*, Florida Geol. Ann. Rept. 20, pl. 3, fig. 3a–b. (After Clark and Twitchell.)

Oligopygus colsoni LAMBERT, 1931, Soc. géol. France Bull., sér. 5, t. 1, p. 290, pl. 17, figs. 1–4.

Occurrence.—GEORGIA: Bainbridge (well, depth 70 feet, type, fide Conrad); station 3293, A. H. Brooks, collector; station 3390, T. W. Vaughan, collector; station 6171, L. W. Stephenson, collector; station 7097, C. W. Cooke and W. C. Mansfield, collectors); Blue Spring, 4 miles below Bainbridge (station 3380, T. W. Vaughan, collector); Red Bluff, Flint River, 6 miles above Bainbridge (station 3387, T. W. Vaughan, collector; station 6159, L. W. Stephenson, collector); half a mile above Red Bluff (station 7099, C. W. Cooke, collector); 7¼ miles from Bainbridge (station 3770, S. W. McCallie, collector); Dry Bread Shoals, Flint River, 8½ miles below Newton (station 7126, C. W. Cooke, collector); Normans Ferry, Flint River, 21½ miles below Newton (station, 7127, C. W. Cooke, collector); Chattahoochee River at Saffold (station 8241, H K. Shearer, collector); 4 miles below Saffold (station 6761, C. W. Cooke, collector).

FLORIDA: Ocala (U. S. Nat. Mus. 112506, 164661, Clark and Twitchell's figured specimens, Joseph Willcox, collector; station 6804, C. W. Cooke, collector); Oakhurst Lime Co., 2 miles southeast of Ocala (station 6805, C. W. Cooke, collector); Zuber, 6½ miles north of Ocala (station 6807, C. W. Cooke collector); 1¼ miles south of Newberry (station 6812, C. W. Cooke, collector); 1½ miles northwest of Newberry (station 6814, C. W. Cooke, collector); old French phosphate mine east of Anthony (station 7366, C. W. Cooke, collector); Johnson's lime sink, Levy County (station 365, L. C. Johnson, collector); Willow Sink, Levy County (station 7367, C. W. Cooke, collector); 2 miles northeast of Sumterville (station 12751, W. C. Mansfield and C. W. Mumm, collectors); Kendrick, 4.8 miles north of Ocala (station 14125, W. C. Mansfield and C. W. Mumm, collectors); 3½ miles southeast of Floral City (station 14133, W. C. Mansfield and C. W. Mumm, collectors); 2½ miles southeast of Ocala (station 14137, W. C. Mansfield and C. W.

Mumm, collectors); 5 miles south of Ocala (station 14181, W. C. Mansfield and C. W. Mumm, collectors); north of Marianna (type of *colsoni*, Colson collector, fide Lambert); 12 miles north of Marianna (stations 14152, 14182, W. C. Mansfield and C. W. Mumm, collectors); 3 miles northeast of Newberry (station 14177, W. C. Mansfield and C. W. Mumm, collectors; station 13843, W. C. Mansfield and F. S. MacNeil, collectors); 3½ miles northeast of Newberry (station 14178, W. C. Mansfield and C. W. Mumm, collectors); 1 mile east of Newberry (station 14180, W. C. Mansfield and C. W. Mumm, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Remarks.—This, the most common species of *Oligopygus*, is distinguished from other species of the genus by the location of its periproct, which is near the posterior end. Attention should be called to Clark and Twitchell's misspelling of the specific name—a mistake that has been copied by subsequent writers.

OLIGOPYGUS ROTUNDUS Cooke, n. sp.
Plate 2, figures 1–3

Ambitus nearly circular; upper surface inflated; lower surface flatter. Apical system central, tumid, with four genital pores. Petals nearly straight, tumid, open at the distal ends, extending about three-fourths the distance to the ambitus; interporiferous zones about twice as wide as poriferous zones; pores circular; pores of a pair connected by a groove. Peristome nearly circular, deeply sunken in a tubular depression. Peristomial depression transversely elliptical, about twice as long as wide, plainly delimited from the rest of the lower surface; anterior wall slightly overhanging, posterior wall nearly vertical, lateral walls steeply sloping upward towards the peristome. Periproct small, round, flush, about one-third the distance from the ambitus to the peristrome.

Length, 22.2 mm.; width, 20.3 mm.; height, 13.3 mm.

Occurrence.—Koons Mill on Cripple Creek, Geneva County, Alabama (Alabama Geol. Survey, T. H. Aldrich, collector).

Geologic horizon.—Late Eocene, probably Moodys marl.

Type.—U. S. Nat. Mus. 498991, deposited by Alabama Geol. Survey.

Remarks.—This species is represented by three slightly corroded but otherwise well preserved individuals. The matrix is light-gray glauconitic, sandy, calcareous marl containing "Nummulites."

Oligopygus rotundus resembles *O. haldemani* (Conrad), but its upper surface and petals are more tumid, its periproct is farther from the ambitus, and its peristomial depression is more sharply delimited, steeper, and narrower. The species apparently did not grow so large as *O. wetherbyi* and *O. floridanus*, its periproct is nearer the ambitus, and its outline is more nearly circular. Its proportions are similar to *O. collignoni* Lambert (1931, p. 291, pl. 17, figs. 5–7), but its lower surface appears to be flatter, and its peristomial depression is shorter and wider.

Genus AMBLYPYGUS Agassiz, 1840

Amblypygus AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, pp. 5, 17.
Amblypygus AGASSIZ, and DESOR, *1847*, Catalogue raisonné des échinides, p. 108.
Amblypygus D'ORBIGNY *1855*, Paléontologie française, Terrain crétacé, Échinides irreguliers, p. 373.
Amblypygus DESOR, *1858*, Synopsis des échinides fossiles, p. 255.
Amblypygus COTTEAU, *1865*, Échinides fossiles des Pyrénées, p. 109.
Amblypygus DE LORIOL, *1875*, Schweizer. paleont. Gesell. Verh., Band 2, p. 43.
Amblypygus DUNCAN and SLADEN, *1883*, Palaeontologia Indica, ser. 14, vol. 1, pt. 4, p. 12.
Amblypygus POMEL, *1883*, Classification méthodique et genera des échinides, p. 59.
Amblypygus COTTEAU, *1887*, Palétontologie française, Échinides éocènes, t. 1, p. 487.
Amblypygus LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 341.

Genotype, *Amblypygus dilatatus* Agassiz and Desor (1847, p. 109; Cotteau, 1887, p. 488, pls. 130, 131), from the Eocene of France, designated by Duncan and Sladen (1883, p. 15).

Amblypygus is very closely related to *Echinoneus*, the most conspicuous difference being in the outer row of ambulacral pores, which are circular throughout in *Echinoneus* but elongate and slotlike above the ambitus in *Amblypygus*. Both genera have four genital pores, but in *Echinoneus* the anterior and posterior pairs are farther apart than in *Amblypygus*.

AMBLYPYGUS AMERICANUS Desor

Amblypygus americanus DESOR, *1858*, Synopsis des échinides fossiles, p. 256.
Amblypygus merrilli TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 165. pl. 76, figs. 1a–d; pl. 57, figs. 1a–b, 2a–b; pl. 78, figs. 1a–b.
Amblypygus americanus JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 55.
Amblypygus americanus ARNOLD and CLARK, *1927*, Harvard College Mus. Comp. Zoology Mem., vol. 50, no. 1, p. 25, pl. 3, figs. 1–3.

Occurrence.—FLORIDA: Kendrick lime quarry near Ocala (station 4246, U. S. Nat. Mus. 164934, type of *merrilli*, G. P. Merrill, collector); Clark, Alachua County (station 2825, U. S. Nat. Mus. 137870, L. M. Everett, collector); Newberry (station 6812, C. W. Cooke, collector).
GEORGIA: Chattahoochee River above US 84 near Saffold (station 12100, C. W. Cooke and W. H. Monroe, collectors); near Albany (Florida Geol. Survey I-1382, G. Winthrop, collector).
JAMAICA: Type; Mt. Sinai region of the Yallahs River district, St. Thomas Parish (Mus. Comp. Zoology, B. W. Arnold, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Mus. Comp. Zoology 724 (a plaster cast of the original, No. Y 5).

Remarks.—The specimens from the United States are higher than those from Jamaica, which also show more variation in shape, some being plainly elongated (fide Arnold and Clark). This difference in height probably is merely individual variation. The nearest related living species, *Echinoneus cyclostomus*, also is variable in shape.

Genus ECHINONEUS Leske, 1778

Echinoneus LESKE, *1778*, Naturalis dispositio echinodermatum, p. 173.
Echinonëus A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 117, 332.
Echinoneus POMEL, *1883*, Classification méthodique et genera des échinides, p. 54.
Echinonëus A. AGASSIZ, *1909*, Am. Jour. Sci., ser. 4, vol. 28, pp. 490–492.
Echinonëus WESTERGREN, *1911*, Harvard College-Mus. Comp. Zoology Mem., vol. 39, no. 2, pp. 41–44.
Echinoneus H. L. CLARK, *1917*, idem, vol. 46, no. 2, p. 101.
Echinoneus LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 330.
Echinoneus GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. in Math. and Phys. Sci., vol. 2, p. 103.

Genotype, *Echinoneus cyclostomus* Leske, living in warm oceanic waters, designated by H. L. Clark, 1917.

ECHINONEUS CYCLOSTOMUS Leske

Echinoneus cyclostomus LESKE, *1778*, Naturalis dispositio echinodermatum, p. 173, pl. 37, figs. 4, 5.
Echinonëus cyclostomus A. AGASSIZ, *1872*, 1873, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 117, 550, pl. 14, figs. 6–8; pl. 14a, figs. 5–10.
Echinonëus cyclostomus WESTERGREN, *1911*, idem, vol. 39, no. 2, p. 44, pls. 1–28.
Echinoneus cyclostomus H. L. CLARK, *1917*, idem, vol. 46, no. 2, p. 192.
?Echinoneus cyclostomus JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 54, pl. 9, figs. 4, 5.

Occurrence.—Widely distributed in shallow warm waters.

Geologic horizon.—Recent. Jackson (1922, p. 54) reports this species from the Anguilla limestone (early Miocene), but the identification seems open to question.

Genus TREMATOPYGUS d'Orbigny, 1885

Trematopygus D'ORBIGNY, *1855*, Paléontologie française, sér 1, t. 6, p. 374.
Nucleolites Lamarck (part). DESOR, *1858*, Synopsis des échinides fossiles, p. 262.
Trematopygus POMEL, *1883*, Classification méthodique et genera des échinides, p. 57.
Plagiochlasma POMEL, *1883*, idem, p. 59.
Dochmostoma DUNCAN, *1891*, Linnean Soc. London Jour., Zoology, vol. 23, p. 176.
Trematopygus LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 338.

Genotype, *Nucleolites olfersi* Agassiz (d'Orbigny, 1855, p. 376, pl. 949), from the Neocomian of Europe, designated by Lambert and Thiéry, 1921.

TREMATOPYGUS CRUCIFER (Morton)

Ananchytes cruciferus MORTON, *1830*, Am. Jour. Sci., ser. 1, vol. 18, p. 245, pl. 3, fig. 8.
Nucleolites crucifer MORTON, *1833*, Am. Jour. Sci., ser. 1, vol. 23, p. 294.
Trematopygus crucifer D'ORBIGNY, 1855, Paléontologie française, Terrain crétacé, t. 6, p. 387, pl. 953, figs. 10, 11; pl. 963, figs. 1–5.
Trematopygus crucifer CLARK, *1893*, U. S. Geol. Survey Bull. 97, p. 63, pl. 27, figs. 1a–i.
Trematopygus cruciferus CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 71, pl. 28, figs. 3a–c; pl. 29, figs. 1a–f.
Lichnidius crucifer LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 341.

Occurrence.—NEW JERSEY: Rancocas Creek, Vincentown (U. S. Nat. Mus. 29470).

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia 1464.

Remarks.—The original spelling *crucifierus*, corrected by Morton to *crucifer*, should be regarded as a *lapsus calami* and the correction permitted to stand.

Family CLYPEASTRIDAE A. Agassiz, 1873

Genus CLYPEASTER Lamarck, 1801

Clypeaster LAMARCK, *1801*, Système des animaux san vertèbres, p. 349.
Clypeaster DESOR, *1858*, Synopsis des échinides fossiles, p. 239.
Clypeaster MICHELIN, *1861*, Soc. géol. France Mém., sér. 2, t. 7, no. 2, p. 101.
Stolonoclypeus A. AGASSIZ, *1863*, Harvard College Mus. Comp. Zoology Bull., vol. 1 p. 25. (Genotype, *Clypeaster prostratus* Ravenel = *Echinanthus subdepressus* Gray, designated by H. L. Clark, 1911, p. 595).
Clypeaster POMEL, *1883*, Classification méthodique et genera des échinides, p. 68.
Echinorodum POMEL, *1883*, idem, p. 68. (Genotype *Echinus rosaceus* Linnaeus, here designated. Proposed as subgenus of *Clypeaster*.)
Diplothecanthus DUNCAN, *1891*, Linnean Soc. London Jour., Zoology, vol. 23, p. 153. (Genotype, *Echinus reticulatus* Linnaeus = *E. rosaceus* Linnaeus.)
Clypeaster H. L. CLARK, *1911*, Annals and Mag. Nat. History, ser. 8, vol. 7, p. 604.
Clypeaster H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 20.
Clypeaster LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 7, p. 298.

Genotype, *Echinus rosaceus* Linnaeus, living in the West Indian region, fixed by elimination by Lamarck (1816, p. 13; see H. L. Clark, 1911, p. 594).

CLYPEASTER ROSACEUS (Linnaeus)

Echinus rosaceus LINNAEUS, *1758*, Systema naturae, ed. 10, p. 665.
Clypeaster rosaceus LAMARCK, *1801*, Système des animaux sans vertèbres, p. 349.
Clypeaster rosaceus H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 25, pl. 123, fig. 1.
Diplothecanthus rosaceus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 219, pl. 102, figs. 1a–b; pl. 103, figs. 1a–b.
Diplothecanthus dalli TWITCHELL, *1915*, idem, p. 218, pl. 99, figs. 2a–b; pl. 100, figs. 1a–b.
Clypeaster rosaceus JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 33,
Clypeaster dalli JACKSON, *1922*, idem, p. 37, pl. 4, fig. 1.

Occurrence.—South Carolina to West Indies (living).

FLORIDA: Caloosahatchee River 2¼ miles below LaBelle (station 4955, F. G. Clapp, collector); Four-mile Hammock, between Ft. Thompson and Denaud (station 2094, W. H. Dall, collector, type of *Diplothecanthus dalli*); about 1 mile below LaBelle (Florida Geol. Survey station I-209).

DOMINICAN REPUBLIC: Gato (Rodolfo Cambiarso, collector).

Geologic range.—Pliocene, Caloosahatchee marl, to Recent.

Remarks.—The Recent *Clypeaster rosaceus* is very variable in height, degree of inflation of the petals, and in other features. Two of the three specimens in the United States National Museum from the Caloosahatchee marl, named *dalli* by Twitchell, have somewhat more inflated petals than the other, which Twitchell identified as *rosaceus*. The specimen from the Dominican Republic figured as *dalli* by Jackson also is more inflated than most living *rosaceus*. A larger suite of fossils might reveal constant differences between the Recent and the fossil forms, but the differences in the material at hand seem to be merely individual variations.

CLYPEASTER SUBDEPRESSUS (Gray)

Plate 4, figure 5

Echinanthus subdepressa GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 427.
Clypeaster subdepressus A. AGASSIZ, *1874*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 306, pl. 11b; pl. 11e, figs. 1, 2; pl. 12d, fig. 4; pl. 13, figs. 10–18.
Clypeaster subdepressus H. L. CLARK, *1914*, idem, vol. 46, p. 38, pl. 123, figs. 11, 12.

Occurrence.—South Carolina to Brazil (living).

SOUTH CAROLINA: Intracoastal Waterway Canal about 3 miles southwest of Little River, (Charleston Museum, G. Robert Lunz, collector; S. F. Blake, collector; station 13377, C. W. Cooke, collector).

Geologic range.—Pliocene, Waccamaw formation, to Recent.

Figured specimen.—U. S. Nat. Mus. 499007, S. F. Blake, collector.

Remarks.—The odd petal of the fossils is slightly shorter, broader, and more closely rounded at the distal end than that of Recent specimens; and the margin of the larger fossils is somewhat thicker than is customary today. But these differences are so slight and the Recent specimens are so variable that it seems hardly worth while to apply a new name to the fossils, which probably are the ancestors of specimens living in the same region. The largest specimen collected by Mr. Lunz is about 155 mm. long and 140

mm. wide. The figured specimen is 70 mm. long.

CLYPEASTER ROGERSI (Morton)

Scutella rogersi MORTON, *1834*, Synopsis organic remains Cretaceous, p. 77, pl. 13, fig. 3.
Lagana rogersi AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, p. 6.
Scutella jonesii FORBES in LYELL, *1845*, Geol. Soc. London Proc., vol. 4, p. 574, text fig.; idem, Quart. Jour., vol. 1, p. 440, text fig.
Clypeaster rogersi CONRAD, *1866*, Smithsonian Misc. Coll., vol. 7 (200), p. 22.
Scutella (*Mortonia*) *rogersi* (part) DE GREGORIO, *1890*, Mon. faune éocenique de l'Alabama, p. 250, pl. 43, fig. 16. (After Morton. Not description nor figs. 17–20).
Clypeaster douvillei STEFANINI, *1911*, Soc. geol. italiana Boll. 30, p. 682, p. 22, figs. 1a–c.
Clypeaster rogersi CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 136, pl. 64, figs. 2a–d, 3a–d.
Clypeaster rogersi COOKE, *1926*, Alabama Geol. Survey Special Rept. 14, pl. 97, fig. 7.
Clypeaster rogersi COOKE and MOSSOM, *1929*, Florida Geol. Survey Ann. Rept. 20, pl. 7, fig. 7. (After Cooke.)
Not *Scutella rogersi* Morton. AGASSIZ, *1841*, Mon. échinodermes vivans et fossiles, Mon. 2, p. 85, pl. 19a, figs. 1–4 (=*Periarchus quinquefarius* (Say)).
Not *Mortonia rogersi* (Morton). DESOR, *1858*, Synopsis des échinides fossiles, p. 231.

Occurrence.—ALABAMA: Monroe County (type); 2 miles east of Howard's Landing, 7 miles southwest of Claiborne, Monroe County (station 2329, Frank Burns, collector); road from Claiborne to Perdue Hill (station 6729, C. W. Cooke, collector); Clarksville, Clarke County, (Alexander Winchell, collector); 2 miles southwest of Whatley, Clarke County (station 7157, C. W. Cooke, collector); 5 miles south of Jackson Clarke County (station 3296, north side of Salt Mountain, T. W. Vaughan collector); St. Stephens Bluff, Tombigbee River, Washington County (station 12167, C. W. Cooke, R. B. Stewart, and W. H. Monroe, collectors); 2½ miles north of Millry, Washington County (station 6702, C. W. Cooke, collector) Whitsett's quarry 3 miles south of Collomburg, in Washington County (station 7208, figured by Cooke, 1926, C. W. Cooke, collector); Leck's place near Rescueville, Choctaw County (station 2894, Charles Schuchert, collector); Rock House Bluff, Conecuh River (stations 6750, 6752, C. W. Cooke, collector); Murder Creek 2 miles above Castleberry (station 7210, C. W. Cooke, collector); Feagin, Conecuh River, Covington County (station 306, L. C. Johnson, collector).

FLORIDA: Marianna (stations 6767, C. W. Cooke, collector; 14330, W. C. Mansfield, and F. S. MacNeil, collectors); Suwannee River opposite Dowling Park (station 12313, W. C. Mansfield and G. M. Ponton, collectors); Suwannee River opposite Ellaville (stations 6824, C. W. Cooke, collector; 12310, lower bed, W. C. Mansfield and G. M. Ponton, collectors); 6 miles below Ellaville (station 12740, W. C. Mansfield, Herman Gunter, and G. M. Ponton, collectors); Miley rock pit in sec. 36, T. 20, R. 18 E., Citrus County (station 14554, C. W. Cooke and W. D. Havens, collectors); Duncan Church, sec. 36, T. 4 N., R. 14 W., Washington County (W. C. Mansfield and C. W. Mumm, collectors).

GEORGIA: Flint River 8 miles below Bainbridge (station 3766, S. W. McCallie, collector); near Hawkinsville (stations 2309, 2311, Frank Burns, collector; R. M. Harper, collector; station 7387, Ocmulgee River about 2 miles below Hawkinsville, C. W. Cooke, collector; station 3967, right bank of river just below wagon bridge, S. W. McCallie, collector; station 2314, south of Big Creek, 5 miles southwest of Hawkinsville, Frank Burns, collector); fork of Brier and Beaverdam Creeks, Screven County, (type of *jonesii*); Brier Creek at Thompson's Bridge, 9 miles east of Waynesboro (station 3663, T. W. Vaughan, collector).

MISSISSIPPI: Hilltop south of Eucutta Creek 5 miles west of Shubuta (station 334, Frank Burns, collector, figured by Clark and Twitchell); Tiger Hill on East Tallahala Creek, sec. 7, T. 1 N, R. 12 E., 10 miles southeast of Bay Springs (station 7735, C. W. Cooke, collector); Bay Springs-Silvarena road (station 7374, 4½ miles west of Bay Springs, C. W. Cooke and E. N. Lowe, collectors; station 7680, 3½ or 4 miles west of Bay Springs, C. W. Cooke, collector; station 7375 east of Tallahala Creek, C. W. Cooke, collector); Chickasawhay River 1¼ miles northwest of the mouth of Limestone Creek, Wayne County (station 13384, C. W. Cooke, collector); Horton Mill Creek 12 miles southeast of Boyce (station 14922, C. W. Cooke, collector); railroad cut 7½ miles south of Jackson, (station 7373, C. W. Cooke, collector); station 14864, F. S. MacNeil, collector); Byram (stations 6455, C. W. Cooke, collector; 9966, A. F. Crider, collector; 12174, C. W. Cooke, R. B. Stewart, and W. H. Monroe, collectors); Vicksburg (station 6451, waterfall in Mint Spring Bayou, C. W. Cooke, collector; U. S. Nat. Mus. 480021, T. L. Casey, collector).

Geologic horizon.—Middle and late Oligocene; Marianna limestone, Byram formation and its Glendon limestone member, and Flint River formation.

Type.—Probably Acad. Nat. Sci. Philadelphia.

Remarks.—*Clypeaster rogersi* is very common in middle and late Oligocene deposits. The species is subject to considerable variation in outline, thickness of margin, and degree of tumidity; but the several varieties usually occur together. Specimens from the Byram near Ellaville (stations 12310, 12740, 12744), Dowling Park (station 12313), and from the Marianna limestone at Marianna, Fla., have thinner margins and are more

tumid centrally than customary, but these features can be matched in selected individuals from Alabama and Mississippi.

CLYPEASTER OXYBAPHON Jackson
Plate 8, figure 7

Clypeaster oxybaphon JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 44, pl. 7, figs. 3, 4; pl. 8, figs. 1–3.

Occurrence.—WEST INDIES: Antigua, north side of Willoughby Bay (type, station 6881, T. W. Vaughan, collector); Puerto Rico, several localities (Am. Mus. Nat. History, C. A. Reeds, collector).

FLORIDA: NW ¼ sec. 36, T. 4. N., R. 13 W., Washington County (station 15068, F. S. MacNeil, collector).

Geologic horizon.—Late Oligocene; Antigua formation, Suwannee limestone.

Type.—Holotype, U. S. Nat. Mus. 328241; paratypes, 328242, 328243. Figured specimen, station 15068, U. S. Nat. Mus. 499006.

Remarks.—This species differs from *Clypeaster rogersi* chiefly in that its margin is thicker than its submargin. It is more depressed above and less deeply concave below than the specimens from the United States referred to *Clypeaster cotteaui*. It bears considerable resemblance to *Laganum elongatum* Egozcue (1897, pl. 4), which appears to be a *Clypeaster*.

CLYPEASTER COTTEAUI Egozcue

Clypeaster cotteaui EGOZCUE, *1897*, Com. Mapa Geol. España Bol., vol. 22, p. 40, pl. 10, figs. 1–4.

Clypeaster cotteaui JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 41, p. 6, figs. 6–8.

Occurrence.—WEST INDIES: Cuba (type); Jamaica; Antigua.

GEORGIA: Worth County on road from Isabella to Albany, 6.4 miles west of Isabella and about 12 miles east of Albany (station 7995, C. W. Cooke, collector).

ALABAMA: Quarry ¼ mile northwest of Adams Crossroads on lower Hacoda-Florala road 8 miles east of Florala (stations 14511, 14604a, F. S. MacNeil, collector; identification doubtful, may be *C. rogersi*).

FLORIDA: Duncan Church, SE ¼ sec. 36, T. 4 N., R. 14 W., 6 miles southwest of Chipley (station 12724, W. C. Mansfield and F. S. MacNeil collectors); Cedar Grove, 2 miles south of Chipley (station 14278, too poor for certain identification); Westville-Geneva road ½ miles south of State line in Holmes County (station 10104, C. W. Cooke and Julia Gardner, collectors). All specimens from Florida may be *C. rogersi*.

Geologic horizon.—Late Oligocene, Suwannee limestone and Flint River formation.

Type.—Comisión del Mapa Geológico de España.

Remarks.—The petals of *Clypeaster cotteaui*, as identified by Jackson (1922), are like those of *C. rogersi*, but the margin is thicker, and the oral surface is more deeply concave and lacks conspicuous ambulacral grooves.

CLYPEASTER GATUNI Jackson
Plate 1, figure 15

Glypeaster gatuni JACKSON, *1917*, U. S. Nat. Mus. Proc., vol. 53, no. 2218, p. 491, pl. 63, fig. 1; pl. 64, fig. 1, 1917.

Clypeaster gatuni JACKSON, *1919*, U. S. Nat. Mus., Bull. 103, p. 105, pls. 47, 48.

Occurrence.—CANAL ZONE: Near Gatun Dam, (station 5662, type, D. F., MacDonald, collector); swamp north of Ancon Hill and ¼ mile south of Diablo Ridge (station 6237, D. F. MacDonald, collector).

FLORIDA: One mile below Bailey's Ferry, Chipola River, Calhoun County (station 2213, Frank Burns, collector U. S. Nat. Mus. 164671, figured).

Geologic horizon.—Early Miocene; Gatun formation (type) and Emperador limestone in Canal Zone; Chipola formation in Florida.

Type.—U. S. Nat. Mus. 324453.

Remarks.—Only one specimen, about half as large as the type, has been found in Florida.

Family SCUTELLIDAE Agassiz, 1841

Genus PERIARCHUS Conrad, 1866

Mortonia DESOR, *1858*, Synopsis des échinides fossiles, p. 231. (Not *Mortonia* Gray, 1851)

Mortonia (*Periarchus*) CONRAD, *1866*, Smithsonian Misc. Coll. vol. 7 (200), p. 21.

Mortonella POMEL, *1883*, Classification méthodique et génera des échinides, p. 70.

Periarchus GRABAU and SHIMER, *1910*, North American index fossils, vol. 2, p. 591.

Mortonella STEFANINI, *1911*, Soc. geol. italiana Boll., vol. 30, p. 684.

Periarchus STEFANINI, *1911*, idem., p. 687.

Mortonella LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 316.

Periarchus LAMBERT and THIÉRY, *1914*, idem., p. 316.

Mortonella CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 128.

Periarchus CLARK and TWITCHELL, *1915*, idem., p. 130.

Genotype, *Sismondia alta* Conrad, 1865, a variant of *Scutella lyelli* Conrad, 1834,

from the late Eocene Castle Hayne marl of North Carolina, designated by Stefanini (1911, p. 687).

Periarchus has five genital pores; open, slender, rather short petals, in which one or two pairs of pores extend beyond the rounded tip; twice-branching ambulacral furrows on the lower surface carrying buccal tubes; and many internal stalactitic pillars and partitions around the margin. *Mortonia* (genotype *Scutella quinquefaria* Say) differs from *Periarchus* only in its generally thicker margin and somewhat less distal periproct, both variable features.

PERIARCHUS LYELLI (Conrad)

Scutella lyelli CONRAD, *1834*, Acad. Nat. Sci. Philadelphia Jour., ser. 1, vol. 7, p. 152.
Scutella pileus-sinensis RAVENEL, *1844*, Acad. Nat. Sci. Philadelphia Proc., vol. 2, p. 97.
Scutella sp. EMMONS, *1858*, Agriculture of the eastern counties, p. 308, figs. 247, 248.
Sismondia alta CONRAD, *1865*, Acad. Nat. Sci. Philadelphia Proc., ser. 2, vol. 9, p. 74.
Periarchus pileus-sinensis STEFANINI, *1911*, Soc. geol. italiana Boll., vol. 30, p. 688, pl. 22, figs. 4a–b, 5a–b.
Periarchus altus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 130, pl. 58, figs. 1a–e.
Periarchus lyelli CLARK and TWITCHELL, *1915*, idem, p. 131, pl. 61, figs. 2a–f; pl. 62, figs. 1a–c, 2a–d.
Periarchus pileus-sinensis CLARK and TWITCHELL, *1915*, idem., p. 135, pl. 63, figs. 1a–e, 2a–d.

Occurrence.—NORTH CAROLINA: Craven County (type of *Sismondia alta*); Castle Hayne phosphate works, New Hanover County (station 4286, L. W. Stephenson, collector); Northeast Cape Fear River 3¼ miles above Castle Hayne (L. W. Stephenson, collector; station 10616, L. B. Kellum, collector); city quarry, near Wilmington (station 3602, Frank Burns, collector; station 3609, T. W. Vaughan, collector; station 4285, L. W. Stephenson, collector; station 7302, B. L. Miller, collector; station 10613, L. B. Kellum, collector); Rocky Point, Pender County (station 779, T. W. Stanton, collector); Moores Creek 2 miles west of Angola and 3 miles northeast of Maple Hill, Pender County, on farm of J. L. Fisher (station 10619, L. B. Kellum, collector); 2 to 2½ miles southwest of Charity, Duplin County (station 11816, W. C. Mansfield collector); 2 miles south of Magnolia, Duplin County, on farm of B. D. Johnson (station 10622, L. B. Kellum, collector); Trent River ¾ mile southwest of Comfort, Jones County (station 10630, L. B. Kellum, collector); 10 miles northwest of Jacksonville, Onslow County, on J. J. Thomas' farm (station 10636, L. B. Kellum, collector); 1 mile west of Maple Cypress, Craven County, on farm of Douglas Green (station 12007, W. C. Mansfield, collector); Cove Creek, Craven County (type of *Sismondia alta*).

SOUTH CAROLINA: About 6 miles south of Black Oak Lock of Santee Canal, Berkeley County, on estate of Dr. Philip G. Prioleau (type of *Scutella pileus-sinensis*); Santee Canal (U. S. Nat. Mus. 5133, Col. Totten, collector).

GEORGIA: Ring Jaw Landing on Oconee River 2 miles west of Kittrell's, Johnson County (station 3961, S. W. McCallie, collector) 2½ miles southeast of Stony Creek Church, Twiggs County, (station 7432, J. E. Brantly, collector); 3 miles north of Adams Park, Twiggs County, on land of Col. Minter (station 7437, C. W. Cooke, collector); Marion road 0.4 mile southwest of Bond's store, Bibb County, 9 miles south of Macon (station 7695, C. W. Cooke, collector); Blue Ruin plantation, Houston County, 10 miles east-northeast of Montezuma (station 7690, C. W. Cooke, collector); Georgia Southern and Florida Railway ½ mile south of Tivola, Houston County (station 3760, S. W. McCallie, collector); quarry at Clinchfield, 1 mile south of Tivola (stations 7689, 12098, C. W. Cooke, collector; 13183, J. W. Rhodes, collector; 10499, C. W. Cooke and T. M. Prettyman, collectors); Elko road 2 miles south of Perry (station 3966, S. W. McCallie, collector) Ross Hill, Elko road 3½ miles south of Perry (stations 5535 and 5536, T. W. Vaughan, collector; 5540, Otto Veatch, collector; 7683, 7684, C. W. Cooke, collector); Elko road 4½ miles south of Perry (station 5588, Otto Veatch, collector); railway ¼ mile north of Bonaire, Houston County (station 3970, S. W. McCallie, collector); Boughton place, 2 miles northwest of Westlake, Houston County (station 8270, J. E. Brantly, collector); Small's place 4 miles east of Kathleen, Houston County (station 8272, J. E. Brantly, collector); Pennahatchee Creek about 1 mile above its mouth, Dooly County (station 12022, C. W. Cooke and W. H. Monroe, collectors); Flint River ¼ mile below the mouth of Spring Creek, Sumter County (station 7107, C. W. Cooke and J. E. Brantly, collectors); Big Shellstone Creek on Deese plantation, 5 miles north-northeast of Coley, Bleckley County (stations 2310, S. W. McCallie, collector; 7433, J. E. Brantly, collector); Ainslie, Bleckley County (station 7434, J. E. Brantly, collector); the Brooks farm, 12 miles southeast of Marshallville, Macon County (station, 3993, S. W. McCallie, collector); 3 miles southeast of Marshallville (station 3975, S. W. McCallie, collector); 4 miles south of Marshallville (station 3786, S. W. McCallie, collector); Rich Hill, Crawford County 5½ miles east-southeast of Knoxville (stations 3604, T. W. Vaughan, collector; 4004, S. W. McCallie, collector; 4959, L. W. Stephenson, collector); Chattahoochee River below Lower Gordon Landing, Early County, 1½ miles above Alaga, Ala. (station 8253, C. W. Cooke and O. B. Hopkins, collectors); Chattahoochee River ½ mile above Alaga (station 8255, C. W. Cooke and O. B. Hopkins, collectors); Chattahoochee River at railway bridge near Saffold, Early County (station 8249, H. K. Shearer, collector); Chattahoochee River above highway bridge at Saffold

(station 12100, C. W. Cooke and W. H. Monroe, collectors).

FLORIDA: Pit between Inglis and Yankeetown, Levy County (station 14544, C. W. Cooke and W. D. Havens, collectors); drainage ditch in Citrus County on Florida 15, 5.2 miles northwest of Crystal River.

ALABAMA: Chattahoochee River 1 mile below Lower Gordon's Landing (station 7265, L. C. Johnson, collector); Chochtawhatchee River at railway bridge at Geneva (station 6757, C. W. Cooke, collector); 100 yards above the mouth of Pea River (station 10039, C. W. Cooke and Julia Gardner, collectors); Pea River 1½ miles southwest of Geneva (station 8864, F. G. Clapp, collector); falls of Double Bridges Creek 5 miles east of Samson, Geneva County (stations 8859, 8861, F. G. Clapp, collector); Conecuh County (station 393, L. C. Johnson, collector); Sepulga River opposite Ward's sawmill, sec. 8., T. 3 N., R. 13 E. (station 6745, C. W. Cooke, collector); railway ¾ mile south of Drewry, Monroe County (station 6720, C. W. Cooke, collector); Claiborne (type of *Scutella lyelli*, stations 2393, Frank Burns, collector; 5556, 5565, T. W. Vaughan, collector); Alabama River below Marshallville (station 295, L. C. Johnson, collector); east of Jones Field Branch, in sec. 35, T. 8 N., R. 3 E., 5 miles southeast of Whatley, Clarke County (station 7161, C. W. Cooke, collector); 1 mile southwest of Rockville, Clarke County (station 6158, G. C. Matson, collector); Gopher Hill, Tombigbee River, Washington County (stations 5605, T. W. Vaughan, collector; 6087, George Little, collector); 4 miles west of Silas, Choctaw County (station 7878, O. B. Hopkins, collector); Fail road south of Willow Branch, 4 miles southwest of Silas (station 7215, C. W. Cooke, collector); 1 mile west of old Cocoa Postoffice, Choctaw County (station 2896, L. C. Johnson, collector).

MISSISSIPPI: Shubuta Creek 2½ miles north of Shubuta, Clarke County (station 331, Frank Burns, collector); Chickasawhay River near Shubuta (station 332, Frank Burns, collector); prairies 2 miles southwest of Shubuta (station 335, Frank Burns, collector); railroad cut southwest of the pumping station at Jackson (station 12172, C. W. Cooke, R. B. Stewart, and W. H. Monroe, collectors); NE corner sec. 32, T. 10 N., R 13 E., ½ mile west of Frost Bridge, Wayne County (station 14280, W. C. Mansfield and F. S. MacNeil, collectors).

LOUISIANA: Below the ferry landing at Montgomery, Grant Parish (station 2638, T. W. Vaughan, collector, fragments presumably of this species).

Geologic horizon.—Late Eocene, Castle Hayne marl (North Carolina), Santee limestone (South Carolina). Lower part of the Ocala limestone (Georgia and Alabama), Moodys marl (Alabama, Mississippi and Louisiana).

Type.—Probably Acad. Nat. Sci. Philadelphia; type of *Sismondia alta*, U. S. Nat. Mus. 498960, deposited by Williams College.

Remarks.—*Periarchus lyelli* is very abundant and variable. The variety occurring at Claiborne, Ala., near which the type is reported to have been found, is gently convexly tumid. All gradations exist between this typical form and the conical variety with slightly concave slopes to which Ravenel applied the name *pileus-sinensis*. As these variations occur in the same bed and at many different places, there seems to be no reason for retaining both names, unless one wishes to distinguish as varieties the end members of the series, which are widely different in appearance. The holotype of *Sismondia alta* has wider interporiferous zones and narrower poriferous zones than is customary in *Periarchus lyelli*, which normally shows some variation in these features. I regard it as an aberrant form of *P. lyelli*. Other specimens from North Carolina are conspicuously subtriangular but in other respects resemble typical *P. lyelli*. This subtriangular variety occurs also at several places near Geneva, Ala. The specimens from Florida have rounded petals very like those of var. *alta*.

PERIARCHUS PROTUBERANS Twitchell

Periarchus protuberans TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 133, pl. 62, figs. 3a–f.

Occurrence.—MISSISSIPPI: Shubuta Creek 2½ miles north of Shubuta, Clarke County (station 331, type, Frank Burns, collector); Chickasawhay River near Shubuta (station 332, Frank Burns, collector).

Geologic horizon.—Late Eocene, Jackson group.

Type.—U. S. Nat. Mus. 164685.

PERIARCHUS QUINQUEFARIUS (Say)

Scutella 5-faria SAY, *1825*, Acad. Nat. Sci. Philadelphia Jour., ser. 1, vol. 5, p. 228.

Scutella rogersi Morton. AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 85, pl. 19a, figs. 1–4.

Mortonia rogersi (Morton). DESOR, *1858*, Synopsis des échinides fossiles, p. 231.

Mortonia quinquefaria CONRAD, *1866*, Smithsonian Misc. Coll., vol. 7 (200), p. 32.

Mortonella rogersi (Morton). POMEL, *1883*, Classification méthodique et génera des échinides, p. 70.

Scutella (*Mortonia*) *rogersi* Morton. DE GREGORIO, *1890*, Mon. faune éocenique de l'Alabama, p. 250, pl. 43, figs. 17–20 (not fig. 16).

Mortonella rogersi (Agassiz, not Morton). STEF-

ANINI, *1911*, Soc. geol. italiana Boll., vol. 30, p. 685, pl. 22, figs. 2, 3.
Mortonella quinquefaria CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 128, pl. 60, figs. 2a–f; pl. 61, figs. 1a–b.

Occurrence.—GEORGIA: Near Milledgeville, (types); spring and lime sink 1 mile southwest of the court house at Sandersville, Washington County (stations 3955, S. W. McCallie, collector; 10489, C. W. Cooke and T. M. Prettyman, collectors; 5250, T. W. Vaughan, collector; 7705, C. W. Cooke, collector); quarry of Atlantic Lime Rock Co. 1½ miles south of Sandersville (station 12099, C. W. Cooke and W. H. Monroe, collectors); cut on Central of Georgia Railway between mileposts 138 and 139, Washington County (station 3959, S. W. McCallie, collector); Dublin road 4.6 miles southwest of Tennille, Washington County, at crossing of Central of Georgia Railway (station 10500, C. W. Cooke and T. M. Prettyman, collectors); 1½ miles northwest of Tennille (station 3761, S. W. McCallie, collector); T. W. Smith's farm 2¼ miles south of Warthen, Washington County (station 3953, S. W. McCallie, collector); 1 mile south of Waynesboro, Burke County (station 10504, C. W. Cooke and T. M. Prettyman, collectors).

Geologic horizon.—Late Eocene, Sandersville limestone member of the Barnwell formation.

Types.—Acad. Nat. Sci. Philadelphia.

Remarks.—*Periarchus quinquefarius* seems to be restricted to the vicinity of Washington and Burke counties, Georgia. Say's types could not have come from very near Milledgeville, for that town is situated on ancient igneous and metamorphic rocks. Old labels referring this species to Alabama can not be trusted; the error is due to a regrettable confusion with *Clypeaster rogersi* (Morton), whose type came from Alabama.

PERIARCHUS KEWI Cooke, n. sp.

Plate 1, figures 12–14

Test circular, margin weakly fluted, thin, covered with small tubercles. Apical region tumid; five genital pores at the same distance from the center as the apical ends of the petals. Petals nearly closed at the apical ends; wider open at the outer ends; interporiferous zones somewhat narrower than poriferous zones, nearly straight, widening slightly distally; inner pores round, connected by grooves with the slot-shaped outer pores; petals extending three-fifths the way to the margin. Petals encircled by a tumid ring, which gives the submarginal area a bevelled appearance. Base flat; ambulacral furrows branching about halfway to the margin; buccal tubes extending to the bifurcation. Peristome nearly circular, sunken, about twice as large as the periproct. Periproct small; midway between the peristome and the margin.

Length, 49 mm.; width, 51 mm.; height, 10 mm.; diameter of peristome, 2.5 mm.

Occurrence.—GEORGIA: Highway 341 4.2 miles southeast of Clinchfield, Houston County (U. S. Nat. Mus. 499000, W. S. W. Kew and C. W. Cooke, collectors).

Geologic horizon.—Late Eocene, Cooper marl.

Type.—U. S. Nat. Mus. 499000.

Remarks.—*Periarchus kewi* is closely related to *P. quinquefarius* but differs from that species in its bevelled margin and tumid submarginal band.

Genus ECHINARACHNIUS Gray, 1825

Echinarachnius (part) GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 428.
Echinarachnius AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, pp. 88, 148.
Echinarachnius DESOR, *1858*, Synopsis des échinides fossiles, p. 230.
Scutella (*Echinarachnius*) A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 315.
Phelsumia POMEL, *1883*, Classification méthodique et genera des échinides fossiles, p. 70. Genotype, *Scutella parma* Lamarck, *1816*, here designated.
Echinarachnius H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 66.
Phelsumaster LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 316. Genotype, *Scutella parma* Lamarck.
Echinarachnius GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 56.

Genotype, *Scutella parma* Lamarck, fixed by elimination by Agassiz, 1841. The reason for crediting this genus to Gray rather than to Leske is stated by H. L. Clark (1911, p. 598).

ECHINARACHNIUS PARMA (Lamarck)

Scutella parma LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 11.
Echinarachnius parma GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 428.
Echinarachnius parma AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 89, pl. 20, figs. 9–18.
Echinarachnius parma A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pt. 2, p. 316, pl. 11d, figs. 4, 5; pl. 11e, figs, 4, 5; pl. 12, figs. 1–13.

Echinarachnius parma GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 62, pl. 9, figs. 1, 2; pl. 19, fig. 2; pl. 30, fig. 8.

Occurrence.—Atlantic coast of North America from New Jersey northward and Pacific coast northward from Puget Sound.

Geologic horizon.—Recent.

Remarks.—This species, the common sand dollar of the northern Atlantic coast, has not been reported fossil in North America.

Genus PROTOSCUTELLA Stefanini, 1924

Protoscutella STEFANINI, *1924*, Geol. Soc. America Bull., vol. 35, p. 843.

Genotype, *Scutella mississippiensis* Twitchell.

Stefanini defines this genus as follows:

Scutella mississippiensis Twitch., provided with five genital pores and bifurcated actinal furrows, is very different from the true Miocene Scutellas, which have by definition four genital pores and branching actinal furrows. On the other hand, it differs from *Periarchus* (to which it is, however, more allied), by its more important characters, not so much by the shape, more low and flat, as especially by its periproct on the edge of the test. I apply to this species the name *Protoscutella*. As to *S. tuomeyi* Twitch., it is in some ways intermediate between *Protoscutella* and *Periarchus;* but, notwithstanding its flattened shape, I would include them in the second of these genera, to which it corresponds by the position of the anus. In any case it is not a *Scutella*.

Twitchell and Stefanini (whose knowledge of the species was based entirely on Monograph 54) were mistaken in crediting *Protoscutella mississippiensis* with bifurcated actinal furrows. Each furrow is straight and unbranched, like those of *Clypeaster* but less conspicuous and having one raised thread (buccal tube) near the peristome. The genus may be described thus:

Test low, generally broader than long. Upper surface usually somewhat swollen medially. Lower surface nearly flat, commonly somewhat concave around the margin, having five straight ambulacral furrows and buccal tubes. Margin thin, usually truncated and slightly notched posteriorly, the notch in some individuals extending to the periproct. Apical disk with five genital pores situated (in all the known species) in such a manner that a straight line drawn through two adjacent genital pores passes through an ocular pore. Petals of nearly equal length, extending about halfway to the margin; open at the distal ends and having a few detached pores there. Peristome small, subcircular, flush. Periproct closer to the margin than to the peristome, sometimes marginal, the closeness to the margin depending upon the depth of the posterior notch.

PROTOSCUTELLA MISSISSIPPIENSIS (Twitchell)

Scutella mississippiensis TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 124, pl. 59, figs. 1a–f.
Protoscutella mississippiensis STEFANINI, *1924*, Geol. Soc. Am. Bull., vol. 35, p. 843.
Monostychia mississippiensis LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 583.

Occurrence.—MISSISSIPPI: Cemetery Creek west of Enterprise, Clarke County (station 115, 116, 129, type, L. C. Johnson, collector); Chickasawhay River at Enterprise (stations 346, 2629, Frank Burns, collector); McCanns Creek bluff on Chickasawhay River 4 miles southwest of Enterprise (station 345, Frank Burns, collector).

TEXAS: Mt. Enterprise, in the southeast part of Rusk County (station 2056, L. C. Johnson. collector); San Augustine (stations 512, T. W. Vaughan, collector; 13144, Julia Gardner, collector); 6 miles west of San Augustine on the Nacogdoches road (station 13267, Julia Gardner and W. P. Popenoe, collectors).

Geologic horizon.—Middle Eocene, Winona sand member of the Lisbon formation in Mississippi; Mount Selman formation in Texas.

Type.—U. S. Nat. Mus. 137655.

PROTOSCUTELLA CONRADI (Cotteau)

Sismondia marginalis CONRAD, *1865*, Acad. Nat. Sci. Philadelphia Proc. p. 75. (Not Des Moulins, 1837).
Sismondia conradi COTTEAU, *1891*, Paléontologie française, Échinides éocènes, t. 2, p. 300.
Scutella conradi CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 126, pl. 64, figs. 1a–d.

Occurrence.—SOUTH CAROLINA: Locality not specified (type).

NORTH CAROLINA: Farm of J. A. Stokes 2 miles north of creek near Maple Cypress, Craven County (station 8165, J. A. Cushman, collector); farm of A. R. Bland 1½ miles northeast of Rose Hill, Duplin County (station 10621, L. B. Kellum, collector), farm of T. J. Falkner 3 miles east of Quinerly and 2 miles north of Neuse River, Craven County (station 10627, L. B. Kellum, collector).

Geologic horizon.—Late Eocene, probably Santee limestone in South Carolina, Castle Hayne marl in North Carolina.

PROTOSCUTELLA TUOMEYI (Twitchell)

Scutella tuomeyi TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 125, pl. 60, figs. 1a–d.
Periarchus tuomeyi STEFANINI, *1924*, Geol. Soc. America Bull., vol. 35, p. 843.

Occurrence.—SOUTH CAROLINA: Cave Hall, Orangeburg County, 14 miles south of Ft. Motte (station 2017, Frank Burns, collector).

Geologic horizon.—Eocene, probably Santee limestone or possibly McBean formation.

Type.—U. S. Nat. Mus. 137970.

Remarks.—*Protoscutella tuomeyi*, known only from the type, may prove to be a synonym of *P. conradi*. The most conspicuous difference is in the location of the periproct, which is farther from the margin in *P. tuomeyi*. The posterior margin of *P. tuomeyi* is less strongly notched than that of *P. conradi*. The type is twice as large as that of *P. conradi*.

PROTOSCUTELLA PENTAGONIUM

Cooke, n. sp.

Plate 2, figures 4–6

Test subpentagonal, tumid medially, margin thin, slightly bent down; covered with small tubercles. Apical system central; five genital pores. Petals equal in length, lanceolate, open at the ends, extending halfway to the margin; interporiferous zones about equal in width to the poriferous zones; anterior petal swollen at the apical end, somewhat wider than the others. Lower surface flat except for the turning down of the margin; ambulacral furrows straight, extending almost to the margin. Peristome small, central, round. Periproct round, one-fourth the way from the margin to the peristome; connected with the margin by a shallow furrow.

Length, 30 mm.; width, 30 mm.; height, 6 mm.

Occurrence.—FLORIDA: Well of the Chipley Oil Co. at Falling Water, 4 miles south of Chipley, Washington County (depth unknown probably about 600 feet; embedded in white sand; station 13145, type, C. W. Cooke collector).

TEXAS: Nacodoches County (station 7951, Mr. Bruyere, collector); 12 to 13 mile west of San Augustine on Nacogdoches road (station 13269, Julia Gardner, collector); 5 miles west of San Augustine on Nacogdoches road (U. S. Nat. Mus. 499111, Julia Gardner, collector).

Geologic horizon.—Middle Eocene; probably Lisbon formation in Florida, Mount Selman formation in Texas.

Type.—U. S. Nat. Mus. 498992.

Remarks.—The specimens from Texas, which are rounder and smaller than the type, are somewhat doubtfully identified as this species.

PROTOSCUTELLA PLANA (Conrad)

Scutella crustuloides Morton. MORTON, *1833*, Am. Jour. Sci., vol. 24, pl. 10, fig. 8. (Not description, p. 131.)
Scutella lyelli Conrad. MORTON, *1834*, Synopsis organic remains Cretaceous, p. 77, pl. 10, fig. 8. (Figure same as preceding.)
Sismondia plana CONRAD, *1865*, Acad. Nat. Sci. Philadelphia Proc., p. 75.
Mortonia (Periarchus) planus CONRAD, *1866*, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Sismondia plana COTTEAU, *1891*, Paléontologie française, Échinides éocènes, t. 2, p. 299.
Monostychia plana GREGORY, *1891*, Geol. Soc. America Bull., vol. 3, p. 108.
Periarchus? planus STEFANINI, *1891*, Soc. geol. italiana Boll., vol. 30, p. 699.
Sismondia? plana CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 121, pl. 57, figs. 4a–d.

Occurrence.—SOUTH CAROLINA: Not specified (type); Eutaw Springs, Orangeburg County (stations 7968 and 13391, C. W. Cooke, collector).

NORTH CAROLINA: Farm of J. C. Teachey, Duplin County 3 miles northeast of Teachey depot (station 10620, L. B. Kellum, collector); marl pit 2½ miles southwest of Charity, Duplin County (station 11816, W. C. Mansfield, collector).

Geologic horizon.—Late Eocene, Santee limestone in South Carolina; Castle Hayne marl in North Carolina.

Type.—Acad. Nat. Sci. Philadelphia 1080.

Remarks.—Clark and Twitchell's figure shows that this species is not congeneric with *Sismondia occitana* (the genotype of *Sismondia*) as figured by Cotteau (1891, p. 272, pls. 271, 272, 273, figs. 1–6). The specimens in the National Museum, which have not been compared with the type, have five genital pores, which remove the species from *Sismondia* and *Peronella*, both of which have only four. The unbranched ambulacral furrows remove it from *Periarchus*. The periproct is not marginal, as in *Protoscutella mississippiensis*, but it is not farther from the margin than that of *P. tuomeyi*.

Genus SCUTELLA Lamarck, 1816

Scutella (part) LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, p. 7.

Scutella AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, pp. 75, 147.
Scutella AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes, p. 76.
Scutella DESOR, *1858*, Synopsis des échinides fossiles, p. 231.
Scutella POMEL, *1883*, Classification méthodique et genera des échinides, p. 70.
Scutella COTTEAU, *1891*, Paléontologie française, Échinides éocènes, t. 2, p. 239.
Scutella LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 317.
Scutella GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 53.

Genotype, *Echinodiscus subrotundus* Leske (1778, p. 206, pl. 47, fig. 7; Agassiz, 1841, p. 76, pl. 17), Miocene of Bordeaux, by elimination by Agassiz.

SCUTELLA ABERTI Conrad

Scutella aberti CONRAD, *1842*, Nat. Inst. Promotion Sci. Proc., vol. 2, p. 194.
Scutella alberti MEEK, *1864*, Smithsonian Misc. Coll., vol. 7 (183), p. 2.
Scutella aberti CLARK, *1904*, Maryland Geol. Survey, Miocene, p. 432, pl. 129, figs. 2, 2a; pl. 120, figs. 1a, b, 2a, b.
Scutella aberti CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 187, pl. 86, figs. 1a, b; pl. 87, figs. 1a–d.

Occurrence.—MARYLAND: Jones Wharf, St. Marys County (station 2451, Frank Burns, collector; W. R. Maxon, collector); Governor Run, Calvert County (Maryland Geological Survey); Scientists' Cliffs, Chesapeake Bay 1½ miles north of Governor Run (A. H. Clark, collector; W. F. Foshag, collector); Dover Bridge, Dorchester County (Maryland Geological Survey).

Geologic horizon.—Miocene, Choptank formation.

Remarks.—Clark and Twitchell were mistaken in crediting *Scutella aberti* with five genital pores; it has only four. The species differs from *S. subrotunda* in its ambulacral furrows, which branch much nearer the peristome. The outer ends of its petals are more evenly rounded, its periproct is smaller and farther from the margin, and its posterior notch is much deeper. The depth and shape of the notch, however, are variable in the Maryland species, most individuals being more deeply notched than the one figured by Clark. The individual plates in *Scutella aberti* are very loosely connected and fall apart very easily.

SCUTELLA FLORIDANA Cooke, n. sp.

Plate 4, figures 9, 10

Test large, flat, broader than long; margin thin, sinuous, with a deep, narrow posterior notch. Upper surface gently tumid medially, slightly concave around the margin. Apical system central; madreporite large, star-shaped, with four genital pores at the tips; petals wide, slightly open and broadly rounded or truncate at the tips, extending more than halfway to the margin; poriferous zones widening distally; interporiferous zones narrower at each end than in the middle, where they equal the poriferous zones. Lower surface flat; grooves bifurcating near the peristome. Peristome central, subcircular, with protruding buccal tubes. Periproct round or oval, smaller than the peristome, near the margin.

Length, 106 mm.; width, more than 122 mm.; height, 12.5 mm.

Occurrence.—FLORIDA: Sopchoppy, Wakulla County (station 7468, type, G. C. Matson, collector; station 10972, W. C. Mansfield, collector); Rouse's place, 3 miles west of Sopchoppy (station 4977, F. G. Clapp, collector).

Geologic horizon.—Miocene, Hawthorn formation.

Type.—U. S. Nat. Mus. 498980.

Remarks.—The petals of *Scutella floridana* appear to be blunter at the ends than those of *S. aberti*, its posterior notch is narrower, its periproct is nearer the margin, and its plates are more firmly joined and have less conspicuous sutures. *S. floridana* is closely related to *S. cazonesensis* Kew from the State of Vera Cruz, Mexico, but its interporiferous zones appear to be narrower, its notch is much deeper than that of the type of *S. cazonesensis*, and its periproct is nearer the margin. However, the closeness of the periproct to the margin may depend upon the depth of the notch, which is variable.

Genus ENCOPE Agassiz, 1840

Encope, AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, pp. 6, 17.
Encope AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 45.
Encope AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes, p. 79.
Encope DESOR, *1858*, Synopsis des échinides fossiles, p. 237.
Encope A. AGASSIZ, *1872*, Harvard College Mus Comp. Zoology Mem., vol. 3, p. 324.

Encope POMEL, *1883*, Classification méthodique et genera des échinides p. 71.
Eucope H. L. CLARK, *1911*, Ann. and Mag. Nat. History, ser. 8, vol. 7, p. 599 (*Eucope* by misprint).
Encope, H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem. vol. 46, p. 72.
Encope LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 325, 1921.

Genotype, *Encope grandis* Agassiz, living off the Pacific Coast of the Americas, by monotypy. The description of the genus must serve as the original description of this species, which was later described and figured by Agassiz (1841, p. 57, pl. 6).

ENCOPE EMARGINATA (Leske)
Plate 3, figures 14, 15

Echinodiscus emarginatus LESKE, *1778*, Naturalis dispositio echinodermatum, p. 200, pl. 50, figs. 5, 6.
Encope emarginata AGASSIZ, *1841*. Mon. d'échinodermes, Mon. 2, p. 47, pl. 10.
Encope emarginata A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 325, pl. 12, figs. 14–24; pl. 12b, figs. 1–3; pl. 12d, figs. 2, 3.
Encope emarginata H. L. CLARK, *1914*, idem., vol. 46, p. 74, pl. 125, fig. 25.

Occurrence.—NORTH CAROLINA: Farm of James Dawson 3 miles north of Grifton, Pitt County (figured, U. S. Nat. Mus. 166525, Harvey Bassler, collector); North shore of Lake Waccamaw, Columbia County (station 13379, base of upper bed, F. S. MacNeil, collector); Wilmington (station 3610, fragments, T. W. Vaughan, collector).
SOUTH CAROLINA: Intracoastal Waterway Canal 3 to 5 miles southwest of Little River, Horry County (station 13377, C. W. Cooke, collector; station 13427, W. C. Mansfield and F. S. MacNeil, collectors; S. F. Blake, collector; Charleston Museum, G. Robert Lunz, collector).
LIVING: Uruguay northward to Yucatan, perhaps to South Carolina.

Geologic horizon.—Miocene, Duplin marl, or Pliocene, Waccamaw formation, in North Carolina; Pliocene, Waccamaw formation, in South Carolina; Recent.

ENCOPE MACROPHORA (Ravenel)

Scutella macrophora RAVENEL, *1842*, Acad. Nat. Sci. Philadelphia Jour. ser. 1, vol. 8, pt. 2, p. 334, text fig.
Encope macrophora RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 3.
Encope macrophora TUOMEY and HOLMES, *1857*, Pleiocene fossils of South Carolina, p. 2, pl. 1, fig. 3.
Macrophora raveneli CONRAD, *1865*, Acad. Nat. Sci. Philadelphia Proc., p. 74.
Encope macrophora (part) CLARK and TWITCHELL *1915*, U. S. Geol. Survey Mon. 54, p. 206, pl. 93, figs. 2a–e; pl. 94, fig. 2; not pl. 94, figs. 1a–f.

Occurrence.—SOUTH CAROLINA: The Grove, on Cooper River, Berkeley County (Edmund Ravenel, collector; W. Stimpson, collector).

Geologic horizon.—Pliocene, Waccamaw formation.

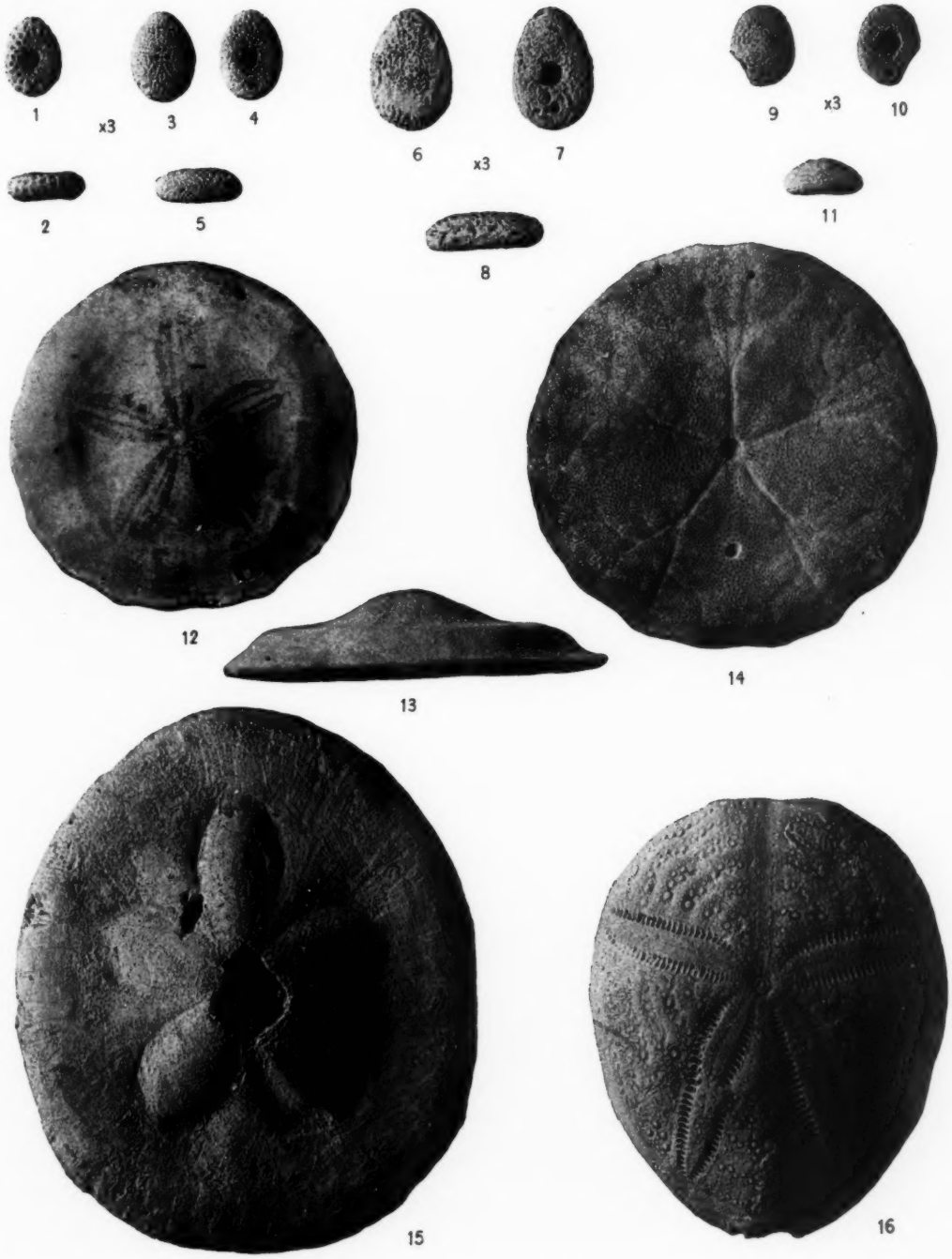
ENCOPE TAMIAMIENSIS Mansfield

Encope macrophora (Ravenel) (part). CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 206, pl. 94, figs. 1a–f.
Encope macrophora tamiamiensis MANSFIELD, *1932*, U. S. Geol. Survey Prof. Paper 170, p. 48, pl. 17, fig. 8.

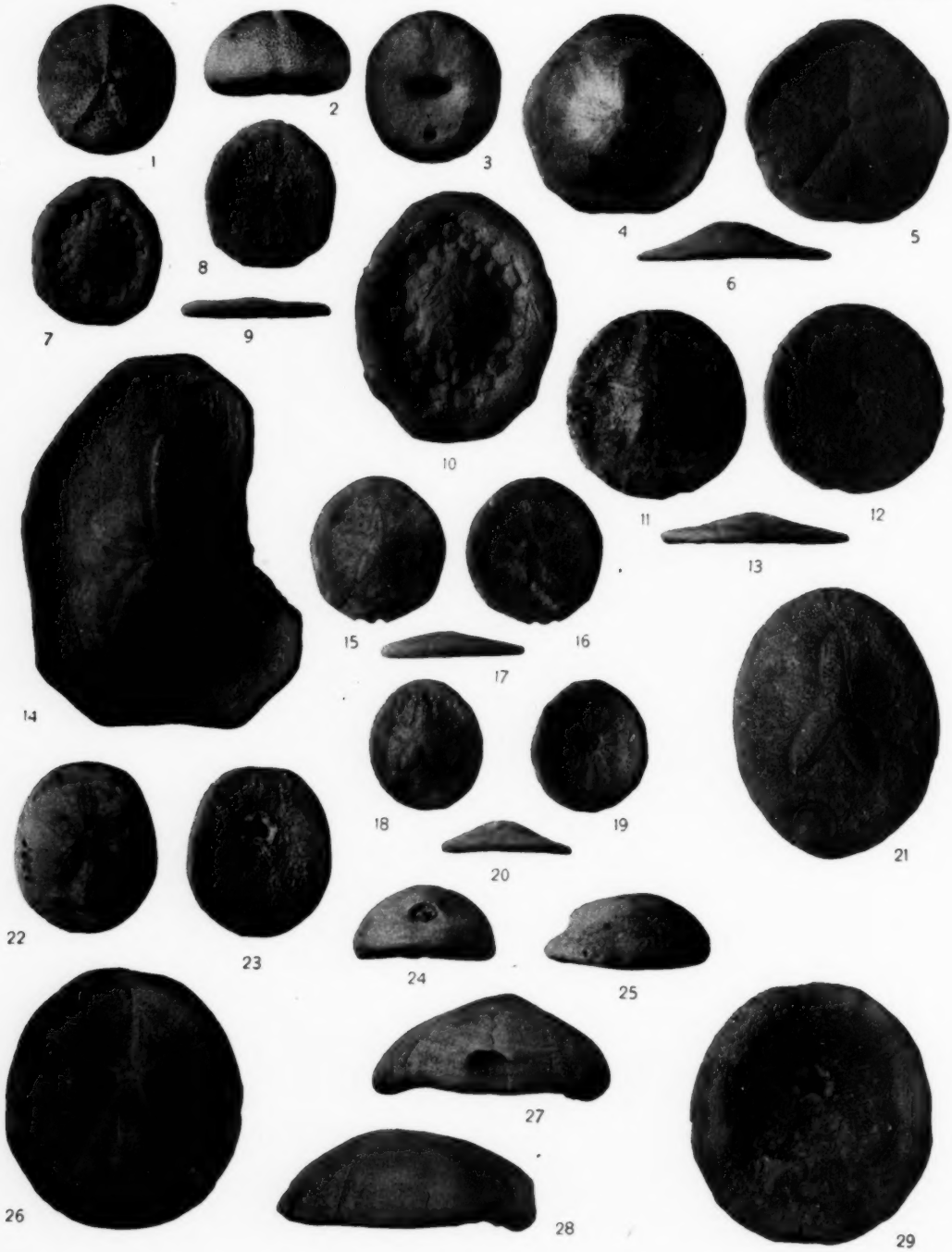
Occurrence.—FLORIDA: Tamiami Trail, Collier County 5 miles east of Carnestown and about 7 miles northeast of Everglades (station 11177, type, C. W. Cooke, W. C. Mansfield, and Stuart Mossom, collectors); Tamiami Trail about 6 miles west of the crossroads leading to Everglades (station 11178, C. W. Cooke, W. C. Mansfield, and Stuart Mossom, collectors); Alligator Creek, Monroe County (Joseph Willcox, collector, figured by Clark and Twitchell); 16 to 22 miles south of Immokalee, Collier County (station 13409, G. M. Ponton, collector); Tamiami Trail 56 miles west of Miami (station 13410, G. M. Ponton, collector; Carnestown, Collier County, 4 miles north of Everglades (station 11180, C. W. Cooke, W. C. Mansfield, and Stuart Mossom, collectors).

EXPLANATION OF PLATE 1

FIGS. *1–5—Echinocyamus huxleyanus* Meyer. *1, 2*, U. S. Nat. Mus. 166503, Claiborne, Ala.; *3–5*, U. S. Nat. Mus. 499001, Geneva, Ala.; all ×3. Late Eocene. (p. 29)
6–8—Echinocyamus parvus Emmons. U. S. Nat. Mus. 499002, 10 miles north of Jacksonville, N. C., ×3. Late Eocene. (p. 28)
9–11—Echinocyamus chipolanus Cooke, n. sp. Holotype, U. S. Nat. Mus. 499003, Alum Bluff, Fla., ×3. Early Miocene. (p. 29)
12–14—Periarchus kewi Cooke, n. sp. *12*, Paratype; *13, 14*, holotype, both U. S. Nat. Mus. 499000, 4.2 miles southeast of Clinchfield, Ga., ×1. Late Eocene. (p. 16)
15—Clypeaster gatuni Jackson. U. S. Nat. Mus. 164671, Baileys Ferry, Fla., ×1 (p. 13)
16—Eupatagus (*Gymnopatagus*) *mooreanus* Pilsbry. U. S. Nat. Mus. 372879, ×1. Late Eocene. (p. 54)



Cooke, Cenozoic Echinoids



Cooke, Cenozoic Echinoids

Geologic horizon.—Pliocene, Caloosahatchee marl.

Type.—U. S. Nat. Mus. 371328.

Remarks.—*Encope tamiamiensis* differs from *E. macrophora* as follows: its lunule is smaller; it is proportionately wider; its margin is thinner; its apical center is farther back; its anterior pair of petals do not lie nearly in a straight line, like those of *E. macrophora*, but form an angle of about 150°; the interporiferous zones of the anterior pair of petals are not nearly straight-sided, like those of *E. macrophora*, but are narrower at the ends than in the middle. These differences appear to be constant.

ENCOPE MICHELINI Agassiz

Plate 4, figure 6

Encope michelini AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 58, pl. 6a, figs. 9, 10.
Encope michelini A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 329, pl. 12b, fig. 4; pl. 12c, figs. 3, 4; pl. 12d, fig. 1.
Encope michelini H. L. CLARK, *1914*, idem. vol. 46, p. 75.
Encope michelini BERRY, *1941*, U. S. Nat. Mus. Proc., vol. 90, no. 3113, p. 444, pl. 63.

Occurrence.—NORTH CAROLINA: Neills Eddy Landing, Cape Fear River, 28 miles above Wilmington (station 4275, L. W. Stephenson and B. L. Johnson, collectors).

SOUTH CAROLINA: Intracoastal Waterway canal about 3 miles southwest of Little River, Horry County (station 13427, W. C. Mansfield and S. F. MacNeil, collectors; S. F. Blake, collector); railroad bridge over Intracoastal Waterway canal 2 miles west of Myrtle Beach, Horry County (S. F. Blake, collector).

FLORIDA: St. Lucie Canal, 1 mile from Lake Okeechobee, Palm Beach County (station 10593, C. W. Cooke, Herman Gunter, and Stuart Mossom, collectors); Biscayne Bay at 13th Street, Miami, about 25 feet below sea level (station 13401, G. M. Ponton, collector); Biscayne Bay at foot of Northeast 39th Street, Miami, depth not over 20 feet (station 13400, G. M. Ponton, collector); Big Pine Key, Monroe County (station 4954, Samuel Sanford, collector).

RECENT: Gulf of Mexico, Florida to Yucatan.

Geologic horizon.—Pliocene to Recent; Waccamaw formation, in North Carolina and South Carolina (station 13427), Caloosahatchee marl in Florida (stations 10593), Pamlico formation in South Carolina (West of Myrtle Beach), and Miami oolite in Florida.

Figured specimen.—U. S. Nat. Mus. 499011, station 13427.

Remarks.—All of the specimens referred to the Pliocene have broad, shallow anterior and anterolateral notches. Some of them are very tumid at the back, and in some of them the lunule is rudimentary. The lunule of the figured specimen has a raised rim and is shaped like that of *E. macrophora*.

Each of the posterior pair of petals is straight, as in *michelini*, not curved around the lunule, as in *macrophora*.

Genus MELLITA Agassiz, 1841

Mellita AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 34.
Mellita AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes, p. 80.
Mellita GRAY, *1851*, Zool. Soc. London Proc., vol. 19, p. 36.

EXPLANATION OF PLATE 2

All figures ×1

FIGS. *1–3—Oligopygus rotundus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498991, Koon's mill on Cripple Creek, Geneva County, Ala. Late Eocene. (p. 9)

4–6—Protoscutella pentagonium Cooke, n. sp. Holotype, U. S. Nat. Mus. 498992, deep well at Falling Water, Washington County, Fla. Middle Eocene. (p. 18)

7–10—Laganum ocalanum Cooke, n. sp. *7–9*, Holotype, U. S. Nat. Mus. 372873, 2 miles north of Sumterville, Fla.; *10*, paratype, U. S. Nat. Mus. 498993, Ocala, Fla. Late Eocene. (p. 23)

11–13—Rumphia archerensis (Twitchell). U. S. Nat. Mus. 498994, deep well in Polk County, Fla. Late Eocene. (p. 27)

14—Rumphia eldridgei (Twitchell). U. S. Nat. Mus. 498999, Steinhatchee River near Clara, Fla. Late Eocene. (p. 27)

15–21—Peronella cubae Weisbord. *15–17*, Variety with several large tubercles, U. S. Nat. Mus. 499115, 6 miles southeast of Crystal River, Fla.; *18–20*, variety with few large tubercles, U. S. Nat. Mus. 499114, Branford, Fla.; *21*, variety with no large tubercles, U. S. Nat. Mus. 498995, Oakfield, Ga. Late Eocene. (p. 25)

22–25—Cassidulus (*Cassidulus*) *trojanus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498996, Troy Spring, Lafayette County, Fla. Late Eocene. (p. 32)

26–29—Cassidulus (*Galerolampas*) *fontis* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498997, deep well at Falling Water, Washington County, Fla. Early Tertiary. (p. 35)

Mellita DESOR, *1858*, Synopsis des échinides fossiles, p. 236.
Mellita A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 319.
Mellita POMEL, *1883*, Classification méthodique et genera des échinides, p. 71.
Mellita H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 76.
Mellita LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 324.
Mellita H. L. CLARK, *1940*, U. S. Nat. Mus. Proc., vol. 89, no. 3099, p. 436.
Mellita GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., p. 101.

Genotype, *Echinodiscus quinquiesperforatus* Leske, living in the western Atlantic, designated (under the name *Mellita testudinata* Klein) by Pomel (1883, p. 71).

MELLITA QUINQUIESPERFORATA (Leske)
Plate 3, figures 12, 13

Echinodiscus quinquiesperforatus LESKE, *1778*, Naturalis dispositio echinodermatum, p. 197, pl. 21, figs. c, d.
Scutella quinquefora LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 9.
Mellita quinquefora AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 36, pl. 3.
Mellita testudinata AGASSIZ, *1841*, idem. p. 40, pl. 4a, figs. 7–9.
Mellita ampla MICHELIN, *1858*, Rev. et Mag. Zoologie, no. 8, p. 5 of reprint, pl. 9.
Mellita quinquefora var. *ampla* HOLMES, *1860*, Post-Pleiocene fossils of South-Carolina, p. 3, pl. 1, figs. 6, 6a–b.
Mellita testudinata A. AGASSIZ, *1872*, *1873*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 141, 538, pl. 11, figs. 13–22; pl. 12a, pl. 12c, figs. 1, 2; pl. 37, figs. 1, 2. Gives additional synonymy.
Mellita quinquiesperforata H. L. CLARK, *1914*, idem, vol. 46, p. 76, pl. 125, figs. 16–21.
Mellita pentapora (Gmelin) CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 225, pl. 106, fig. 1; pl. 107, figs 1a–c.

Occurrence.—LIVING: Massachusetts to Brazil.
SOUTH CAROLINA: Wando River (station 7320, Edmund Ravenel, collector); Simmons Bluff, Yonges Island, on Wadmalaw Sound (station 2023, Frank Burns, collector); "Nordmalan" (probably misprint for Wadmalaw, type of *M. ampla* Michelin).
GEORGIA: Brunswick canal (U. S. N. M. 146633, J. M. Couper, collector).

Geologic horizon.—Pleistocene, Pamlico formation; and Recent.

Figured specimen.—U. S. Nat. Mus. 499012.

Remarks.—The fossil form for which Michelin adopted Holmes' manuscript name of *ampla* is much larger than the Recent form living in the same region, and its petals are somewhat wider open at the ends.

MELLITA QUINQUIESPERFORATA TENUIS
H. L. Clark

Mellita quinquiesperforata tenuis H. L. CLARK, *1940*, U. S. Nat. Mus. Proc., vol. 89, no. 3099, p. 442, pl. 60, fig. 2; pl. 61, fig. 2.

Occurrence.—FLORIDA: Two miles off Sanibel Island (W. J. Clench, collector); Tarpon Springs (E. J. Shadle, collector); Charlotte Harbor (W. H. Dall, collector).

Geologic horizon.—Recent.
Type.—U. S. Nat. Mus. E 5656.

Genus LEODIA Gray, 1852

Leodia GRAY, *1852*, Zool. Soc. London Proc. for 1851, vol. 19, p. 36.
Mellita AUCTORES (part).
Leodia LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 324.
Leodia H. L. CLARK, *1940*, U. S. Nat. Mus. Proc., vol. 89, no. 3099, p. 435.

Genotype, *Leodia richardsonii* Gray, 1852, = *Echinodiscus sexies perforatus* Leske, 1778, by monotypy.

This genus differs from *Mellita* in having a lunule in each of the five ambulacral areas instead of in only four. Moreover, the lunules are formed by the enlargement of pits instead of by the closing of marginal notches.

LEODIA SEXIESPERFORATA (Leske)

Echinodiscus sexies perforatus LESKE, *1778*, Naturalis dispositio echinodermatum, p. 199, pl. 50, figs. 3, 4.
Scutella sexforis LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 9.
Mellita hexapora AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 41, pl. 4, figs. 4–7; pl. 4a, figs. 11, 12.
Mellita similis AGASSIZ, *1841*, idem, p. 45, pl. 4, figs. 1–3.
Leodia richardsonii GRAY, *1852*, Zool. Soc. London Proc. for 1851, vol. 19, p. 36.
Mellita sexforis A. AGASSIZ, *1872*, *1873*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 141, 536, pl. 11, figs. 1–12; pl. 11d, fig. 3. Gives additional synonymy.
Mellita sexiesperforata H. L. CLARK, *1914*, idem, vol. 46, p. 77, pl. 125, figs, 22, 23.

Occurrence.—LIVING: South Carolina to Uruguay.
FLORIDA: Miami (station 4867, John McGonigle, collector).
SOUTH CAROLINA: Wadmalaw River (fide Tuomey and Holmes).

Geologic horizon.—Pleistocene to Recent, Miami oolite and Pamlico formation.

LEODIA CAROLINIANA (Ravenel)

Scutella caroliniana RAVENEL, *1841*, Acad. Nat. Sci. Philadelphia Jour., ser. 1, vol. 8, p. 333, text figure.
Mellita caroliniana RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 4.
?Mellita caroliniana TUOMEY and HOLMES, *1857*, Pleiocene fossils of South Carolina, p. 3, pl. 1, figs. 4, 4a–b.
Mellita caroliniana CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 204, pl. 91, figs. 1a–b; pl. 92, figs. 1a–b.

Occurrence.—SOUTH CAROLINA: The Grove, Cooper River, Berkeley County (type); Davis Landing, Pee Dee River, Florence County (station 7804, L. W. Stephenson, collector, fragment).

Geologic horizon.—Pliocene, Waccamaw formation; or Miocene, Duplin marl.

Remarks.—Tuomey and Holmes record this species also from Goose Creek and Wadmalaw River. The latter place may have been Simmons Bluff, which is Pleistocene. *Leodia caroliniana* evidently is very closely related to *L. sexiesperforata* and may prove to be identical with it. As figured by Tuomey and Holmes, however, *L. caroliniana* has proportionately longer and blunter petals and a smaller star-shaped apical plate.

Family LAGANIDAE Gregory, 1900

KEY TO THE LAGANIDAE OF EASTERN UNITED STATES

1. Five genital pores ..... *Laganum.*
   2. Individual plates of submargin tumid ..... *Laganum ocalanum.*
   2. Individual plates of submargin not tumid ..... *Laganum floridanum.*
1. Four genital pores.
   2. Lower surface flat ..... *Rumphia.*
      3. Test much longer than wide ..... *Rumphia eldridgei.*
      3. Test not much longer than wide ..... *Rumphia archerensis.*
   2. Lower surface concave ..... *Peronella.*
      3. Poriferous zones as wide as interporiferous zones ..... *Peronella dalli.*
      3. Poriferous zones not as wide as interporiferous zones.
         4. Petals narrow at apex ..... *Peronella crustuloides.*
         4. Petals wide at apex ..... *Peronella cubae.*

Genus LAGANUM Link, 1807

Laganum LINK, *1807*, Beschr. Natural.-Sammlung Rostock, no. 3, p. 161.
Lagana GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 427.
Laganum AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 105.
Laganum DESOR, *1858*, Synopsis des échinides fossiles, p. 227.
Laganum A. AGASSIZ, *1874*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 516.
Laganum POMEL, *1883*, Classification méthodique et genera des échinides, p. 69.
Laganum H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 1, p. 44.
Laganum LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 313.

Genotype, *Laganum petalodes* Link (1807) = *Echinodiscus laganum* Leske (1778, p. 204, pl. 22, figs. a–c) = *Laganum bonani* Agassiz (1841, p. 108, pl. 23, figs. 8–12; pl. 22, figs. 25–29; A. Agassiz, 1874, p. 517, pl. 13e, figs. 6, 7), by tautonomy, living from the Philippines to the Carolines and Tasmania. The Eocene species here tentatively referred to *Laganum* differ from the genotype in that their lower surfaces are much flatter and lack conspicuous ambulacral grooves and grooves behind the periproct.

LAGANUM FLORIDANUM Twitchell

Laganum floridanum TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 163, pl. 75, figs. 3a–d.
Echinodiscus floridanus LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 581.
Laganum floridanum COOKE and MOSSOM, *1929*, Florida Geol. Survey Ann. Rept. 20, pl. 3, figs. 5a–b. (After Twitchell.)

Occurrence.—FLORIDA: Johnson's sink, Levy County (station 365, type, L. C. Johnson, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. National Museum 137884.

LAGANUM OCALANUM Cooke, n. sp.

Plate 2, figures 7–10

Outline subpentagonal to oval; margin thick; submargin depressed; petaloidal region tumid; lower surface flat. Individual plates in the area between the thick rim and the petals tumid. Apical system slightly eccentric anteriorly; five genital pores. Petals short, extending about halfway to the margin; nearly closed; poriferous zones much

narrower than interporiferous zones, widely separated at the proximal ends. Peristome very small, pentagonal, central. Periproct about one-quarter way from the margin to the peristome. Tubercles fairly large, of uniform size; more widely scattered on the lower than on the upper surface.

Length of holotype, 22 mm.; width, 19.5 mm.; height, 3.5 mm. Length of paratype, 25.5 mm.; width, 22 mm.; height, 4 mm. A specimen from Ocala is 37 mm. long by 30.7 mm. wide.

Occurrence.—FLORIDA: Pit 2 miles northeast of Sumterville (station 12751, type, W. C. Mansfield and G. M. Ponton, collectors; Florida Geol. Survey station 2317; drainage ditch at Great Wall sink near Sumterville (Florida Geol. Survey station 2318, paratype); old MacDonald quarry one mile north of Istachatta (station 11112, C. W. Cooke and Stuart Mossom, collectors); Ocala (station 6804, C. W. Cooke, collector); Zuber, 6 miles north of Ocala (station 6807, C. W. Cooke, collector); 1½ miles northwest of Newberry (station 6814, C. W. Cooke, collector); 1½ miles south of Newberry (Stuart Mossom, collector); old French phosphate mine east of Anthony (station 7366, C. W. Cooke, collector); near Citra (station 7266, L. C. Johnson, collector); Johnson's sink, Levy County (station 365, L. C. Johnson, collector); 1½ miles west of Croom, Hernando County (station 7364, C. W. Cooke, collector); Suwannee River at Branford (station 7341, C. W. Cooke collector); well at Leesburg (station 2076, L. C. Johnson, collector); 1 mile south of Williston (Florida Geol. Survey station 2319); 6 miles southeast of Crystal River (station 14141, W. C. Mansfield and C. W. Mumm, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Holotype, U. S. Nat. Mus. 372873; paratype, 498993.

Remarks.—This species appears to be closely related to *Laganum floridanum* Twitchell, from which it differs in its strongly tumid submarginal plates, which form conspicuous bumps in the sunken region between the petals and the thickened rim. The apical ends of the poriferous zones of *L. ocalanum* are less incurved than those of *L. floridanum*. The buccal tubes can not be seen in most specimens of *L. ocalanum* but are visible in some from the type locality.

Genus PERONELLA Gray, 1855

Laganum (*Peronella*) GRAY, *1855*, Catalogue of the Recent Echinida or sea eggs in the collection of the British Museum, p. 13.
Laganum (*Peronella*) A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 148, 520.
Peronella POMEL, *1883*, Classification méthodique et genera des échinides, p. 69.
Peronella H. L. CLARK, *1911*, Annals and Mag. Nat. History, ser. 8, vol. 7, pp. 599, 605.
Peronella LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc, 4, p. 312.
Echinodiscus LAMBERT and THIÉRY, *1914*, idem, p. 311; 1925, idem, fasc. 9, p. 580.
Peronella H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 50.
Peronella JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 47.

Genotype, *Laganum peronii* Agassiz (1841, p. 124, pl. 22, figs. 21–24; A. Agassiz, 1872, p. 522, pl. 13e, figs. 4, 5; H. L. Clark, 1914, p. 54, pl. 124, figs. 21, 22), by monotypy, living around Australia and Tasmania. The genotype is unique in that its four genital pores lie well outside the apical region, whereas those of all other known species referred to the genus, recent as well as fossil, lie within or contiguous to the apical region. The location of the genital pores has not generally been regarded as of generic importance, though Lambert and Thiéry base their distinction between *Peronella* and *Echinodiscus* on that feature. Their use of *Echinodiscus* is not valid, for its genotype (*E. bisperforatus* Leske, designated by H. L. Clark, 1911, p. 597) is quite different.

Though the genotype is Recent, all the known American species are late Eocene. Three species from the Ocala limestone are treated herein. Jackson (1922) describes one species (*P. mirabilis*) from the San Fernando formation of Trinidad.

PERONELLA CRUSTULOIDES (Morton)

Scutella crustuloides MORTON, *1833*, Am. Jour. Sci., ser. 1, vol. 24, p. 131 (not pl. 10, fig. 8).
Scutella crustuloides MORTON, *1834*, Synopsis organic remains Cretaceous, p. 77, pl. 15, fig. 10.
Sismondia crustuloides DESOR, *1858*, Synopsis des échinides fossiles, p. 227.
Mortonia (*Periarchus*) *crustuloides* CONRAD, *1866*, Smithsonian Misc. Coll., vol. 7 (200), p. 21.
Scutella crustuloides DE GREGORIO, *1890*, Mon. faune éocenique de l'Alabama, p. 251, pl. 43, figs. 24, 25. (After Morton, 1834).
Sismondia crustuloides COTTEAU, *1891*, Paléontologie française, Échinides éocènes, t. 2, p. 300.
Periarchus? crustuloides STEFANINI, *1911*, Soc. geol. italiana Boll., vol. 30, p. 699.
Laganum? crustuloides CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 122, pl. 57, figs. 5a–d, 6a–d.

Laganum johnsoni TWITCHELL, *1915*, idem, p. 162 pl. 75, figs. 2a–d.
Echinodiscus crustuloides LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 581.
Echinodiscus johnsoni LAMBERT and THIÉRY, *1925*, idem, p. 581.
Laganum johnsoni COOKE, *1926*, Alabama Geol. Survey Special Rept. 14, pl. 96, fig. 2.

Occurrence.—Morton's type was collected by T. A. Conrad in the Southern States, probably in Alabama, where the species is abundant.

ALABAMA: Turk's Cave in sec. 19, T. 4 N., R. 13 E., Conecuh County (station 305, type of *Laganum johnsoni* Twitchell, L. C. Johnson, collector; station 10030, C. W. Cooke and Julia Gardner, collectors); Rock Bluff, Conecuh River, in SW. ¼ sec. 28, T. 3 N., R. 14 E. (station 6750, C. W. Cooke, collector; station 10025, figured by Cooke, C. W. Cooke and Julia Gardner, collectors); ¾ mile northwest of Monroeville (station 6722, C. W. Cooke, collector); railroad cut ¾ mile north of Drewry, Monroe County (station 6720, C. W. Cooke, collector).

FLORIDA: Florida Basic Rock Co., 12 miles north of Marianna (station 12058, W. C. Mansfield and G. M. Ponton, collectors; Florida Geol. Survey, G. M. Ponton, collector); Willow Sink, 1½ or 2 miles west of Chiefland, Levy County (station 7367, C. W. Cooke, collector); old French phosphate mine east of Anthony, Marion County (station 7366, C. W. Cooke, collector); Florida (station 3696, J. L. Oliver, collector).

GEORGIA: Bainbridge (station 3390, T. W. Vaughan, collector; station 13611, A. F. Foerste, collector); Red Bluff on Flint River 7 miles above Bainbridge (station 6159, L. W. Stephenson, collector; station 7098, C. W. Cooke, collector); from well on Newton road 7¾ miles north of Bainbridge and ¼ mile from Flint River (station 3770, S. W. McCallie, collector, figured by Clark and Twitchell as *Laganum crustuloides*); Flint River at Dry Bread Shoals 9 miles below Newton (station 7126, C. W. Cooke, collector); Flint River at spring 2 miles below Norman's Ferry, Mitchell County (station 7128, C. W. Cooke, collector); power plant 2 miles north of Albany (station 5054, T. W. Vaughan, collector; station 12040, C. W. Cooke and W. H. Monroe, collectors); well at Cordele, depth 225 feet (station 3814, S. W. McCallie, collector).

Geologic horizon.—Late Eocene; Ocala limestone.

Type.—Probably Acad. Nat. Sci. Philadelphia. Type of *Laganum johnsoni*, U. S. Nat. Mus. 137202.

Figured specimens.—By Clark and Twitchell, U. S. Nat. Mus. 164744; Boston Soc. Nat. History 8802a, deposited in Mus. Comp. Zoology. By Cooke, 1926, as *Laganum johnsoni*, U. S. Nat. Mus. 372896.

Remarks.—As Twitchell suspected, the type of *Laganum johnsoni* proves to be merely an unusually tumid specimen of the species identified by Clark and Twitchell as *Laganum? crustuloides* (Morton). Whether that identification was made from type is not stated, but as they mention no specimens at Philadelphia it is probable that they did not see it; however, as their specimen represents such a common species and agrees so well with Morton's (1834) figure, there is no reason to doubt its correctness.

Morton's (1833, pl. 10, fig. 8) original figure evidently does not represent his *Scutella crustuloides*, which is described as having a thick margin, whereas the figure apparently represents a thin-margined creature, probably *Protoscutella plana* (Conrad). He used the same figure to illustrate *Scutella lyelli* Conrad in 1834 (p. 77, pl. 10, fig. 8).

Peronella crustuloides is very variable in size and shape. The largest specimen in the United States National Museum (from station 10025) measures 55 mm. in length and 45 mm. in width.

PERONELLA CUBAE Weisbord

Plate 2, figures 15–21

Peronella cubae WEISBORD, *1934*, Bull. Am. Paleontology, vol. 20, p. 217, pl. 24, figs. 4–6.
Peronella quinquenodulata WEISBORD, *1934*, idem, p. 214, pl. 24, figs. 1–3.
Peronella caribbeana WEISBORD, *1934*, idem, p. 216, pl. 24, figs. 7–9.

Test oval; upper surface more or less convex; lower surface slightly concave. Apical system central; four small genital pores, very obscure, moderately far apart. Petals wide, short, pointed, extending little more than halfway to the margin, nearly closed at the tips; poriferous zones narrow, slightly incurved at the apical end but wide apart there and almost touching the adjacent petals. Peristome small, central, pentagonal, usually retaining the teeth. Periproct transversely oval, about one-fourth of the distance from the margin to the peristome. Tubercles on the upper surface rather widely spaced, small except a central cluster of larger ones between the genital pores; a few large adventitious tubercles on the interambulacral areas present or not; tubercles on the lower surface larger than the ordinary ones on the upper surface.

The species attained a length of at least 40 mm.

Occurrence.—FLORIDA: Pit of the Crystal River Rock Company about 6 miles southeast of Crystal River, Citrus County (station 14141, W. C. Mansfield and C. W. Mumm, collectors; pl. 2, figs. 15–17, Frank Westendick, collector); Suwannee River at Dowling Springs, (station 7338, C. W. Cooke, collector); east of Steinhatchee River in Dixie County, opposite Clara (station 12747, W. C. Mansfield and G. M. Ponton, collectors; station 14541, C. W. Cooke and W. D. Havens, collectors); Zuber, 6½ miles north of Ocala (station 6807, C. W. Cooke, collector); Alachua Sink, 3½ miles east of Gainesville (station 6799, T. W. Vaughan and C. W. Cooke, collectors; C. W. Cooke and Stuart Mossom, collectors); 2 miles southeast of the cemetery at Alachua (station 13656, Stuart Mossom, collector); 2 miles north of High Springs (station 6787, T. W. Vaughan and C. W. Cooke, collectors); south of Irvings Ferry near Luraville (station 2613, G. H. Eldridge, collector); old MacDonald quarry 1 mile north of Istachatta, Hernando County (station 11112, C. W. Cooke and Stuart Mossom, collectors); Johnson's sink, Levy County (station 365, L. C. Johnson, collector); old French phosphate mine east of Anthony, Marion County (station 7366, C. W. Cooke, collector); 5½ miles southwest of Gainesville (station 14135, W. C. Mansfield and C. W. Mumm, collectors); Kendrick (station 14125, W. C. Mansfield and C. W. Mumm, collectors); pit west of Florida 19, 5 miles south of Salem, Taylor County (station 14539, C. W. Cooke and W. D. Havens, collectors).

GEORGIA: Flint River at mouth of creek in the northeast corner of Dougherty County (station 7235, C. W. Cooke, collector); Flint River about 1¾ miles above the Georgia, Southwestern, and Gulf Railway near Oakfield, Lee County (pl. 2, fig. 21, station 7116, C. W. Cooke, collector).

CUBA: Province of Camagüey, between Nuevitas and Pastellilo; Loma Calisto (Weisbord).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Paleont. Research Inst., Ithaca, N. Y.

Figured specimens.—U. S. Nat. Mus. 498995, 499114, 499115.

Remarks.—The number of large tubercles on *Peronella cubae* is variable; some individuals have more than the figured specimens, many have none. The presence of large adventitious tubercles allies it to *P. mirabilis* Jackson (1922, p. 47, pl. 9, fig. 3), from Trinidad, which, however, has much narrower petals like those of *P. crustuloides*, of which it may prove to be a variant. The greater width of the apical end of the petals distinguishes *P. cubae* from *P. crustuloides*, which usually has a less regularly oval outline but resembles *P. cubae* in its variability in convexity. Many individuals of *P. cubae* are much more tumid than the figured specimens. Several specimens from Florida show the swollen spots within the petals from which *P. quinquenodulata* derived its name.

PERONELLA DALLI (Twitchell)

Laganum dalli TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 164, pl. 75, figs. 4a–d.
Echinodiscus dalli LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 581.
Laganum dalli COLE and PONTON, *1932*, Am. Jour. Sci., ser. 5, vol. 24, p. 23, fig. 1.

Occurrence.—FLORIDA: Archer (type, W. H. Dall, collector); deep well at Leesburg (station 2076, L. C. Johnson, collector); well at Bradenton depth 985–1000 feet (Stuart Mossom, collector); city well at Davenport (found in cleaning the well at a depth of 365 feet, Florida Geol. Survey, collector); well of Palmetto Phosphate Co. near Tiger Bay (I-1600, depth 550 to 620 feet; I-1601, depth 580 feet; I-1602, depth 600 feet, Florida Geol. Survey); well 50 miles west of Miami, depth 1250 feet (E. F. P. Brigham, collector).

GEORGIA: Clinchfield, Houston County (station 14566, C. W. Cooke, collector, imperfect specimen, doubtfully identified).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 164667b.

Remarks.—This species is evidently not a *Laganum*, for it has only four genital pores. Its subpentagonal peristome, its buccal tubes, and its punctate extrapetalous ambulacral regions resemble those of *P. peronii*. In general aspect it resembles *Sismondia occitana* (Defrance), the genotype of *Sismondia*, as figured by Cotteau (1891, p. 272, pl. 271, figs. 1–6) but its petals are nearly closed and rounded at the distal ends and wide open at the apical ends, the opposite of those of *S. occitana*. It is very similar to and perhaps identical with *Sismondia antillarum* Cotteau from the Eocene limestone of St. Bartholomew, but its petals appear to be a little wider and its tubercles a little larger and less numerous than those of the West Indian species. As pointed out by Cole and Ponton, the position of the periproct is variable.

Genus RUMPHIA Desor, 1857

Rumphia DESOR, *1857*, Synopsis des échinides fossiles, fasc. 4, p. 229.
Polyaster MICHELIN, *1859*, Rev. et mag. zoologie, sér. 2, vol. 11, p. 397. Not *Polyaster* Gray, 1840.
Rumphia POMEL, *1883*, Classification méthodique et genera des échinides, p. 69.

Hupea POMEL, *1883*, idem, p. 69. (Genotype, *Scutella decagonalis* Lesson).
Rumphia LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 312.

Genotype, *Laganum rostratum* Agassiz (1841, p. 118, pl. 25), living in New Zealand, by original designation.

RUMPHIA ELDRIDGEI (Twitchell)

Plate 2, figure 14

Laganum eldridgei TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 160, pl. 74, figs. 2a–d.
Rumphia eldridgei STEFANINI, *1924*, Geol. Soc. America Bull., vol. 35, pp. 831, 843.
Rumphia eldridgei COOKE and MOSSOM, *1929*, Florida Geol. Survey Ann. Rept. 20, pl. 3, fig. 7. (After Twitchell.)

Occurrence.—FLORIDA: Suwannee River below a sulphur spring 17 miles below Ellaville (station 2612, type, G. H. Eldridge, collector); Suwannee River at Dowling Springs, Suwannee County (station 7338, C. W. Cooke, collector; stations 12311 and 12312, W. C. Mansfield and G. M. Ponton collectors; station 14538, C. W. Cooke, collector); Suwannee River above the railway bridge near Wilmarth, Suwannee County (station 7337, C. W. Cooke, collector); Suwannee River 4 to 4½ miles below Ellaville (station 12743, W. C. Mansfield, Herman Gunter, and G. M. Ponton, collectors); 5 miles northwest of Mayo, Lafayette County, on road to Dowling Park (station 11114, C. W. Cooke and Stuart Mossom, collectors); 5.2 miles west of Mayo on road to Perry (station 14537, C. W. Cooke and W. D. Havens, collectors); 1 mile north of Mayo (station I-2413, Florida Geol. Survey, G. M. Ponton, collector); Suwannee River below Troy Springs, Lafayette County (station 7347, C. W. Cooke, collector); Florida 19 east of Steinhatchee River opposite Clara, Dixie County (station 12747, W. C. Mansfield and G. M. Ponton, collectors; station 14158, W. C. Mansfield and C. W. Mumm, collectors); Miley rock pit, sec. 36, T. 20 S., R. 18 E., Citrus County (station 14536, C. W. Cooke, collector); 6 miles southeast of Crystal River (station 14141, W. C. Mansfield and C. W. Mumm, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 164683.

Figured specimen.—U. S. Nat. Mus. 498999, station 12747.

Remarks.—The type is the largest individual of this species yet collected. Smaller individuals have proportionately wider and rounder petals, and their anterior pair of petals is less spreading. The ambulacral furrows on the base of *R. eldridgei* are generally very indistinct.

RUMPHIA ARCHERENSIS (Twitchell)

Plate 2, figures 11–13

Laganum archerensis TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 161, pl. 75, figs. 1a–d.
Echinodiscus archerensis LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 581.
Laganum archerensis COOKE and MOSSOM, *1929*, Florida Geol. Survey Ann. Rept. 20, pl. 3, figs. 6a–b. (After Twitchell.)
?Scutella camagüeyana WEISBORD, *1934*, Bull. Am. Paleontology, vol. 20, p. 220, pl. 24, figs. 13, 14.

Occurrence.—FLORIDA: Archer (type, W. H. Dall, collector); Bennett's bone bed, Nixon, Levy County (station 355, L. C. Johnson, collector); Suwannee River near the bridge on Florida 19 east of Oldtown (Florida Geol. Survey I-2329); Cummer Lumber Company phosphate mine near Newberry (Florida Geol. Survey I-1582, G. M. Ponton, collector); 3 miles northeast of Newberry (station 14177, W. C. Mansfield and C. W. Mumm, collectors); 3½ miles northeast of Newberry (station 14178, W. C. Mansfield and C. W. Mumm, collectors); 3 miles north of Newberry (station 13843, W. C. Mansfield and F. S. MacNeil, collectors); pit north of Florida 15-A between Inglis and Yankeetown, Levy County (station 14544, C. W. Cooke and W. D. Havens, collectors); Polk County oil-prospecting well, depth unknown (Florida Geol. Survey I-1580).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 164667a.

Figured specimen.—U. S. Nat. Mus. 498994, deposited by Florida Geol. Survey, I-1580.

Remarks.—This species, described from a single small specimen, is now well represented in collections. A specimen from station 14544 measures 37.5 mm. in diameter—more than twice as large as the type. The species is referred to *Rumphia* because of its four genital pores and flat base with ambulacral grooves.

Family ECHINOCYAMIDAE Cooke, n. fam.

Test small, depressed, with rudimentary, wide-open, few-pored petals. Interambulacra bordered within by low vertical partitions, which radiate toward the peristome.

Genus ECHINOCYAMUS Leske, 1778

Echinocyamus VAN PHELSUM, *1774*, Brief aan Cornelius Nozeman, over de Gewelvslekken of Zee-egelen.
Echinocyamus (part) LESKE, *1778*, Naturalis dispositio echinodermatum, p. 215.

Fibularia (part) LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 16.
Echinocyamus AGASSIZ, *1841*, Mon. d'échinodermes, Mon. 2, p. 125.
Echinocyamus DESOR, *1858*, Synopsis des échinides fossiles, p. 217.
Echinocyamus A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 304.
Echinocyamus POMEL, *1883*, Classification méthodique et genera des échinides, p. 73.
Fibularia LAMBERT, *1891*, Soc. géol. France Bull., sér. 3, t. 19, pp. 749–752.
Echinocyamus COTTEAU, *1892*, Paléontologie française, Échinides éocènes, t. 2, p. 348.
Echinocyamus H. L. CLARK, *1911*, Ann. and Mag. Nat. History, ser. 8, vol. 7, pp. 598, 605.
Echinocyamus H. L. CLARK, *1914*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 59.
Fibularia LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 289.

Genotype, *Echinocyamus angulosus* Leske, 1778, = *Spatagus pusillus* Müller, 1776, = *Echinus minutus* Pallas, 1774, living in the Atlantic Ocean and the Mediterranean Sea, designated, according to Agassiz (1841, p. 125), by de Blainville, 1834. This species is figured under the name *Echinocyamus pusillus* by A. Agassiz (1873, p. 505, pl. 11e, fig. 3; pl. 13, figs. 1–8).

Most authors credit *Echinocyamus* to Van Phelsum, 1774, but H. L. Clark (1911, p. 596) refers it to Leske, regarding Van Phelsum's use of it as not binomial. Lambert is of the opinion that all of Van Phelsum's figures, some of which were copied by Leske, represent a swollen, globular species without internal partitions, like the usual interpretation of *Fibularia* Lamarck. Cotteau, however, points out that the figures of Van Phelsum leave much to be desired, and that his specimens are said to have come from America and the Adriatic Sea—regions in which the globular form without partitions is unknown, but in which the flatter form with partitions abounds.

ECHINOCYAMUS PUSILLUS (Müller)

Echinus minutus PALLAS, *1774*, Spicilegia Zoologica, fasc. 10, p. 34 (fide H. L. Clark).
Echinocyamus pusillus A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 111, 304, pls. 11e, fig. 3; pl. 13, figs. 1–8 (gives synonymy).
Echinocyamus minutus H. L. CLARK, *1914*, idem, vol. 46, no. 1, p. 61.
Fibularia pusilla LAMBERT and THIÉRY, *1914*, Nomenclature raisonnée des échinides, fasc. 4, p. 289.

Occurrence.—Moderately deep water off Florida and elsewhere.

Geologic horizon.—Recent.

Remarks.—According to Opinion 107 of the Commission on Zoological Nomenclature, *pusillus* 1776 should not be displaced by *minutus* 1774.

ECHINOCYAMUS PARVUS Emmons
Plate 1, figures 6–8

Echinocyamus parvus EMMONS, *1858*, Agriculture of the eastern counties, p. 307, fig. 244.
Echinocyamus parvus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 119.
Fibularia parva LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 577.
Echinocyamus parvus KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 14.

Occurrence.—NORTH CAROLINA: Craven County (type); farm of J. M. Thomas 10 miles north of Jacksonville, Onslow County (figured specimen, station 10636, L. B. Kellum, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—Mislaid or lost. Possibly at Williams College, Williamstown, Mass.

Figured specimen.—U. S. Nat. Mus. 499002.

Remarks.—The specimen here figured has not been compared with the type, which could not be found at Williams College, where other of Emmons' types were origi-

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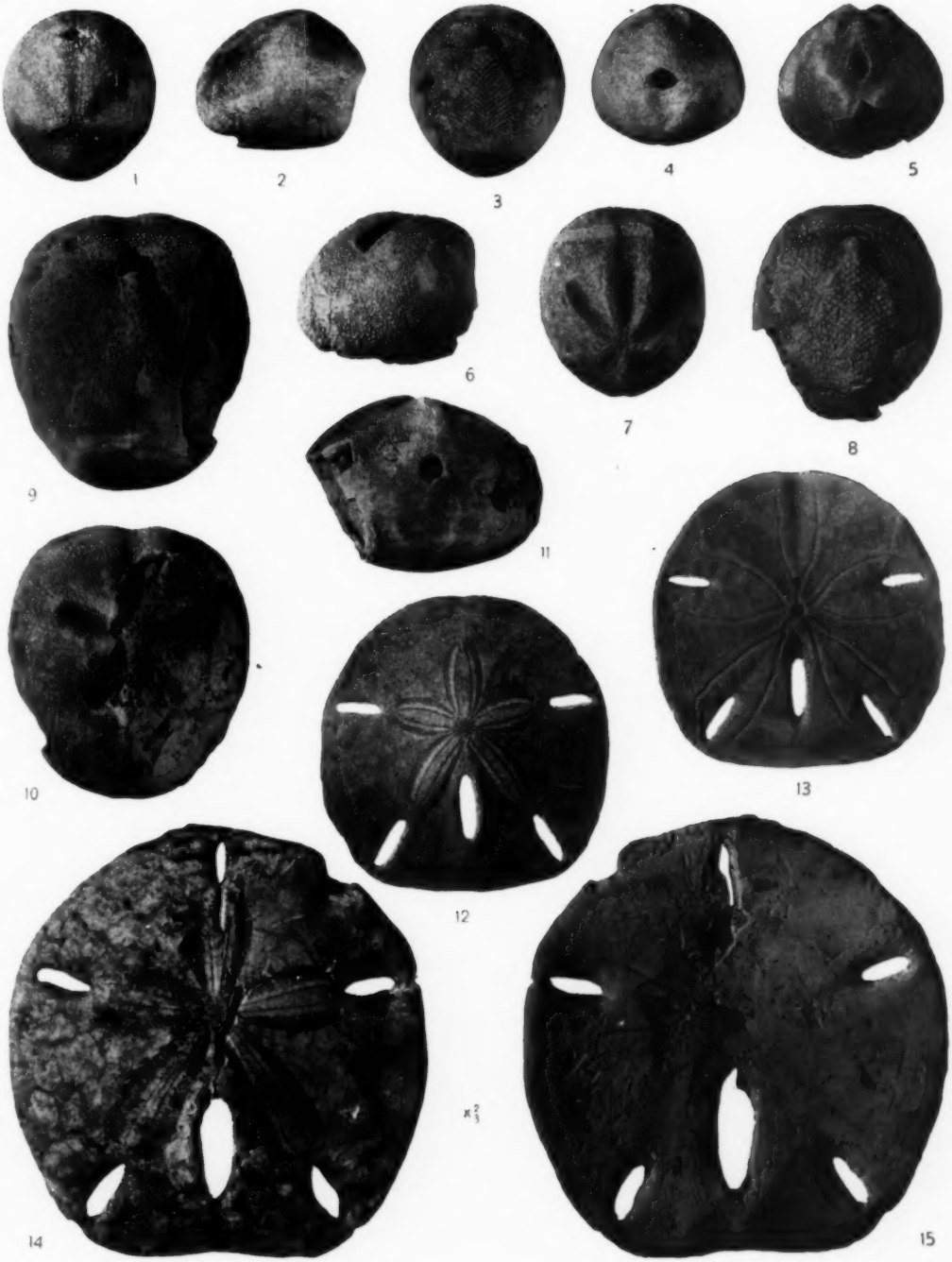
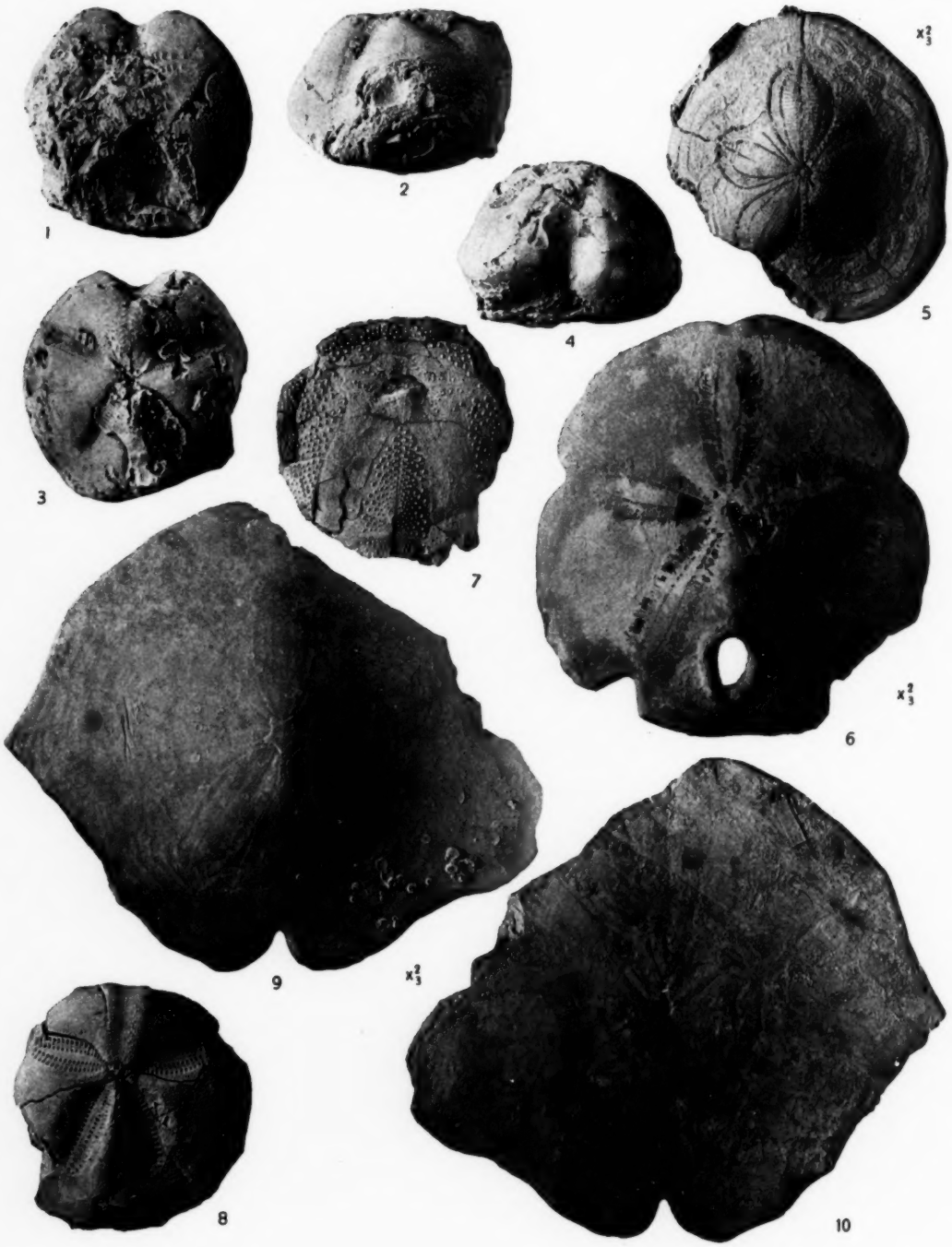
EXPLANATION OF PLATE 3

FIGS. *1–4—Agassizia floridana* de Loriol. U. S. Nat. Mus. 499010, Steinhatchee River near Clara, Fla., ×1. Late Eocene. (p. 44)
5–8—Schizaster beckeri Cooke, n. sp. *5–7*, Holotype, U. S. Nat. Mus. 499008, Arredondo, Fla.; *8*, paratype, U. S. Nat. Mus. 499009, Dowling Park, Fla.; all ×1. Late Eocene. (p. 40)
9–11—Cyclaster drewryensis Cooke, n. sp. Holotype, U. S. Nat. Mus. 372880, Drewry, Ala., ×1. Early Oligocene. (p. 50)
12, 13—Mellita quinquiesperforata (Leske). U. S. Nat. Mus. 499012, Folly Beach, S. C., ×⅔. Recent. (p. 22)
14, 15—Encope emarginata (Leske). U. S. Nat. Mus. 166525, 3 miles north of Grifton, N. C., ×⅔. Late Miocene? (p. 20)



Cooke, Cenozoic Echinoids



Cooke, Cenozoic Echinoids

nally deposited. It is wider behind and narrower in front than Emmon's figure, which is elliptical, but the peristome and periproct are very similar. All of the five specimens from station 10636 have very inconspicuous ambulacral pores. Their four genital pores are much farther apart than those of *E. huxleyanus* Meyer.

ECHINOCYAMUS HUXLEYANUS Meyer
Plate 1, figures 1–5

Echinocyamus huxleyanus MEYER, *1886*, Alabama Geol. Survey Bull. 1, p. 85, pl. 3, fig. 23.
Echinocyamus huxleyanus DE GREGORIO, *1890*, Faune éocenique de l'Alabama, p. 251, pl. 43, fig. 15 (after Meyer).
Echinocyamus huxleyanus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 119, pl. 57, figs. 1a–d.
Fibularia huxleyi (Meyer) LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 577. (Slip of the pen.)

Occurrence.—ALABAMA: Claiborne (type; U. S. Nat. Mus. 166503, T. H. Aldrich, collector); railway bridge at Geneva, Ala. (figured specimen, station 6757, C. W. Cooke, collector).

Geologic horizon.—Late Eocene, Moodys marl (formerly called Gosport sand at Claiborne).

Type.—Johns Hopkins University T 2002.

Figured specimens.—U. S. Nat. Mus. 499001, from Geneva, Ala.; 166503, Claiborne, Ala.

ECHINOCYAMUS MERIDIONALIS Meyer

Echinocyamus meridionalis MEYER, *1887* Senkenberg. naturf. Gesell. Ber. 1887, Vorträge, p. 12, pl. 2, figs. 21, 21a.
Echinocyamus meridionalis DE GREGORIO, *1890*, Faune éocenique de l'Alabama, p. 251, pl. 43, figs. 13, 14. (After Meyer.)
Fibularia meridionalis CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 121, pl. 57, figs. 3a–d.
Fibularia meridionalis LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 9, p. 577.

Original description.—Elliptisch, fast kreisförmig, abgeplattet. After ziemlich nah dem Rande.

Claiborne, Ala.; Jackson, Miss.

Runder und abgeplatteter als *Echinocyamus Huxleyanus* Mr. von Claiborne, auch ist der After kleiner und weiter vom Rand. Das Original ist von Claiborne. Ein Exemplar von Jackson, welches ich zu derselben Art stelle, ist elliptischer.

Occurrence.—Claiborne, Ala. (type); Jackson, Miss.

Geologic horizon.—Late Eocene, Moodys marl.

Type.—Johns Hopkins University T 2005.

Remarks.—This species is represented in the National Museum by a fragment from Claiborne. Its outline is rounder, it is flatter, its periproct is nearer the margin, and its internal marginal partitions are closer together and more numerous than those of *E. huxleyanus*.

ECHINOCYAMUS CHIPOLANUS
Cooke, n. sp.
Plate 1, figures 9–11

Test small, outline broadly oval, gently arched above, flatter below; with surface covered with proportionately large tubercles; strengthened by internal marginal partitions. Genital pores four in number, widely spaced. Ambulacral areas obscure; poriferous zones of each area apparently widely diverging. Peristome about one-third the total width, nearly circular. Periproct very slightly closer to the margin than to the peristome, rather large, slightly pointed posteriorly.

Length, 4 mm.; width, 3.3 mm.; height, 1.3 mm.

Occurrence.—FLORIDA: Lower bed at Alum Bluff, Apalachicola River, Liberty County (station 2211, Frank Burns, collector).

Geologic horizon.—Miocene, Chipola formation.

EXPLANATION OF PLATE 4

FIGS. *1–4—Eupatagus? (Brissopatagus?) primus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498978, 5 miles south of Ellaville, Ga., ×1. Paleocene. (p. 59)
5—Clypeaster subdepressus (Gray). U. S. Nat. Mus. 499007, Intracoastal Waterway Canal 3 miles southwest of Little River, S. C., ×⅔. Pliocene. (p. 11)
6—Encope michelini Agassiz. U. S. Nat. Mus. 499011, 3 miles southwest of Little River, S. C., ×⅔. Pliocene. (p. 21)
7, 8—Eupatagus (Brissopatagus) alabamensis Cooke, n. sp. Holotype, U. S. Nat. Mus. 498979, St. Stephens, Ala., ×1. Late Eocene. (p. 58)
9, 10—Scutella floridana Cooke, n. sp. Holotype, U. S. Nat. Mus. 498980, Sopchoppy, Fla., ×⅔. Early Miocene. (p. 19)

Type.—U. S. Nat. Mus. 499003.

Remarks.—This species is based on a single individual, in which a hole in the left side gives a view of the interior. Its genital pores are much smaller and farther apart than those of *E. huxleyanus*, and its poriferous zones appear to be more widely diverging. It is proportionately shorter and wider than *E. parvus*, and its periproct and peristome are larger.

Genus PORPITELLA Pomel

Porpitella POMEL, *1883*, Classification méthodique et genera des échinides, p. 72.

Genotype, *Scutellina supera* Agassiz (1841, p. 103, pl. 21, figs. 15–19), from the Eocene of France.

Pomel cites two species, *Scutellina hayesiana* Agassiz and *S. porpita* Desor. The first is a synonym of *Scutellina supera*, which Agassiz regarded as perhaps the same as *Cassidulus hayesianus* Desmoulins, 1835, a nude name. *C. hayesianus* Desmoulins is cited by Lambert and Thiéry as the "type unique" of *Porpitella*.

PORPITELLA MICRA H. L. Clark

Porpitella micra H. L. CLARK, *1937*, Jour. Paleontology, vol. 11, no. 3, p. 248, text figs. 1–8.

Occurrence.—ALABAMA: Cuttings from a well (Oakley Estate no. 2) sec. 9, T. 3 N., R. 29 E., Houston County, depth 3800–4000 feet.

Geologic horizon.—Eocene, Lisbon formation or older.

Types.—Holotype, Alabama Mus. Nat. History no. 85, Tuscaloosa, Alabama. Paratypes in Alabama Mus. Nat. History, Mus. Comp. Zoology, and U. S. Nat. Mus.

Family CASSIDULIDAE Agassiz and Desor, 1847

Genus CASSIDULUS Lamarck, 1801

Cassidulus LAMARCK, *1801*, Système des animaux sans vertèbres, p. 348.
Rhyncholampas A. AGASSIZ, *1869*, Harvard College Mus. Comp. Zoology Bull., vol. 1, p. 270.
Rhyncholampas H. L. CLARK, *1917*, idem, Mem., vol. 46, p. 105.

Genotype, *Cassidulus caribœarum* Lamarck (1801, p. 349), living in the Caribbean Sea. As pointed out by Grant and Hertlein, this species is the only possible type of *Cassidulus* because the two other names mentioned in the original description were nude. H. L. Clark (1917, p. 105) designated this same species as the genotype of *Rhyncholampas* A. Agassiz, 1869, and proposed to abandon *Cassidulus* because he deemed it to be preoccupied, but *Cassidulus* is valid under the International Rules, and *Rhyncholampas* becomes a synonym.

No one seems to have questioned the reference of *Cassidulus caribœarum* and *Pygorhynchus pacificus* A. Agassiz to the same genus, yet the two species as figured show marked differences, particularly in the region of the peristome. Agassiz's figures of *caribœarum* are enlarged photographs of a small, presumably immature individual, and Lütken's figures of the same species may be inaccurate. Should these differences prove to be real and important, *Cassidulus*, s.s., may have to be restricted to the genotype. The fossil species here referred to it resemble *C. pacificus* rather than the figures of the genotype.

CASSIDULUS (CASSIDULUS) CARIBŒARUM Lamarck

Cassidulus caribœarum LAMARCK, *1801*, Système des animaux sans vertèbres, p. 349.
Cassidulus caribæarum LÜTKEN, *1864*, Naturh. Forening i Kjobenhavn vidensk. Meddelelser, p. 126, pl. 2, fig. 6.
Rhynchopygus caribaearum A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pt. 2, p. 343, pl. 15, figs. 1–4.
Rhyncholampas caribœarum H. L. CLARK, *1917*, idem, vol. 46, p. 106, pl. 144, figs. 6, 7.

Occurrence.—Caribbean sea.

Geologic horizon.—Recent.

CASSIDULUS (CASSIDULUS) EVERGLADENSIS Mansfield

Plate 8, figures 5, 6

Cassidulus (Rhynchopygus?) evergladensis MANSFIELD, *1932*, U. S. Geol. Survey Prof. Paper 170, p. 48, pl. 18, figs. 1–10.

Occurrence.—FLORIDA: Tamiami Trail 5 miles east of Carnestown and about 7 miles northeast of Everglades, Collier County (station 11177, type, C. W. Cooke, W. C. Mansfield, and Stuart Mossom, collectors); Tamiami Trail 9 miles west of Pinecrest in sec. 13, T. 54 S., R. 32 E. (station 11179, C. W. Cooke, W. C. Mansfield, and Stuart Mossom, collectors); 18 miles south of Immokalee Collier County (Florida Geol. Survey station I-3148, Clarence Simpson, collector; this station was reported as "near Moorehaven" by Mansfield, who was misinformed as to its location).

SOUTH CAROLINA: Intracoastal Waterway canal about 5 miles southwest of Little River and about 15 miles northeast of Myrtle Beach

(station 13377, C. W. Cooke, collector; Charleston Museum, G. Robert Lunz, collector).

Geologic horizon.—Pliocene, Tamiami limestone (Florida) and Waccamaw formation (South Carolina).

Types.—Syntypes, U. S. Nat. Mus. 371329; paratype, U. S. Nat. Mus. 371330.

Figured specimen.—U. S. Nat. Mus. 499005, station 13377.

CASSIDULUS (CASSIDULUS) SABISTONENSIS Kellum

Plate 8, figure 4

Cassidulus (*Pygorhynchus*) *berryi* KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 15, pl. 1, figs. 4–7. Not *Cassidulus berryi* Twitchell, 1915.

Cassidulus (*Pygorhynchus*) *sabistonensis* KELLUM, *1931*, Washington Acad. Sci. Jour., vol. 21, p. 51.

Occurrence.—NORTH CAROLINA: E. W. Sabiston's farm, 2 miles north of Jacksonville, Onslow County (station 10637, type, L. B. Kellum, collector).

Geologic horizon.—Early Miocene?, Trent marl? Kellum reports this species from the Eocene Castle Hayne marl, but the hard sandy matrix resembles the Trent marl. A badly worn individual of *Eurhodia raveneli* (Twitchell) in the same lot probably was reworked from the Eocene.

Remarks.—The petals of *C. sabistonensis* are more like those of *C. evergladensis* Mansfield than those of any other American species, being rounder and less spatulate than other species.

CASSIDULUS (CASSIDULUS) GOULDII (Bouvé)

Pygorhynchus gouldii BOUVÉ, *1846*, Boston Soc. Nat. History Proc., vol. 2, p. 192.

Nucleolites mortoni CONRAD, *1850*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 40, pl. 1, fig. 11.

Ravenelia gouldii MCCRADY, *1859*, Elliot Soc. Nat. History Charleston Proc., vol. 1, p. 283.

Cassidulus (*Pygorhynchus*) *gouldii* CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 171, pl. 79, figs. 3a–d; pl. 80, figs. 1a–f, 2a–d.

Procassidulus (*Hardouinia*) *gouldii* LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 363.

Occurrence.—GEORGIA: Baker County (type); 2½ miles north of Cuthbert (station 4058, S. W. McCallie, collector); A. E. Belcher's well in lot 180, 16th District, Decatur County (station 3755, S. W. McCallie, collector); Leesburg (station 7421, Pierce, collector); Flint River, half a mile below Newton (station 6106, L. W. Stephenson, collector); Georgia Southern and Florida Railway 32 miles south of Macon (station 3783, S. W. McCallie, collector); 2 miles south of Perry (station 3966, S. W. McCallie, collector); Hawkinsville (station 2311, Frank Burns, collector); Abbeville road 3½ miles south of Hawkinsville (station 6194, L. W. Stephenson, collector); 9 miles southwest of Abbeville and half a mile northeast of Center School, Wilcox County (station 10324, C. W. Cooke and T. M. Prettyman, collectors); Albany road 9 miles north of Camilla (station 14921, C. W. Cooke, collector).

FLORIDA: Many places in Alachua, Columbia, Gadsden, Hamilton, Hernando, Hillsborough, Jefferson, Pasco, and Suwannee Counties.

MISSISSIPPI: Heidelberg (U. S. Nat. Mus. 156464, L. C. Johnson, collector); bed of creek in sec. 22 (?), T. 4 N., R. 1 E., about 3½ miles east of Byram (stations 14071a, 14605, F. S. MacNeil, collector, doubtfully identified).

Geologic horizon.—Oligocene, Flint River formation (Georgia) and Suwannee limestone (Florida), Mint Spring marl member of Marianna limestone (?) (Mississippi).

Type.—Boston Soc. Nat. History 1756A (lectotype, a cast of the interior) deposited in Mus. Comp. Zoology, Cambridge, Mass. A plaster cast of this specimen is in the United States National Museum.

Remarks.—*Cassidulus gouldii* is a very abundant and variable species. The type, a silicious cast of the interior from the late Oligocene Flint River formation in Baker County, Ga., is somewhat larger than the average. Its longitudinal profile is tumid anteriorly but nearly straight between the apex and the periproct. Other specimens from Georgia are somewhat tumid posteriorly as well as anteriorly. Individuals from the late Oligocene Suwannee limestone, in which it is very abundant, tend to be more conical, with the highest point anterior to the apical system, like the two specimens from Florida figured by Clark and Twitchell. Most of them are not tumid posteriorly. The specimens from the middle Oligocene Marianna limestone and its Mint Spring marl member of Mississippi have sharper margins than customary.

CASSIDULUS (CASSIDULUS) ALABAMENSIS Twitchell

Cassidulus (*Pygorhynchus*) *alabamensis* TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 172, pl. 80, figs. 3a–d.

Cassidulus (*Hardouinia*) *alabamensis* LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 362.

Occurrence.—FLORIDA: Natural Bridge, Walton County in SE. ¼ sec. 26, T. 6 N., R. 20 W. (type, T. H. Aldrich, collector); Suwannee River opposite Ellaville, lowest bed (station 6824, C. W. Cooke, collector); station 11111, C. W. Cooke and Stuart Mossom, collectors; station 12310, W. C. Mansfield and G. M. Ponton, collectors); lowest bed near mouth of Withlacoochee River (station 12744, W. C. Mansfield and others, collectors).

Geologic horizon.—Middle Oligocene, Byram formation.

Type.—Holotype, Johns Hopkins University (two plaster casts in U. S. Nat. Mus.).

Remarks.—*Cassidulus alabamensis* is very closely related to *C. gouldii* and may prove to be indistinguishable from it. The type is much larger than most specimens referred to either species but is almost equalled in size by a cast of the interior from A. E. Belcher's well in Decatur County, Ga., which was listed by Twitchell as one of the two original localities for *C. alabamensis*. This cast is here referred to *C. gouldii*. The available specimens indicate *C. alabamensis* is more nearly quadrate in outline than *C. gouldii* and more inflated posteriorly. *C. alabamensis* comes from slightly older beds than *C. gouldii*.

The label accompanying the type gives Alabama as the location of Natural Bridge, which, however, is in Florida nearly three-quarters of a mile south of the Alabama line.

CASSIDULUS (CASSIDULUS) TROJANUS Cooke, n. sp.
Plate 2, figures 22–25

Outline subquadrate, wider behind than in front. Upper surface moderately inflated except behind the periproct, where there is a broad, shallow sulcus; rostrate above the periproct. Lower surface flat. Margin acute. Apical system slightly excentric anteriorly; four genital pores, five ocular pores, madreporite central. Petals lanceolate, of nearly equal length, extending somewhat more than halfway to the margin, open at the distal ends; pores round or oval; interporiferous zones wider than poriferous zones; outer poriferous zones of posterior paired petals longer than the inner. Peristome farther forward than the apical system, pentagonal, slightly wider than long. Oral lobes swollen. Phyllodes about as long as the diameter of the peristomial opening. Periproct supramarginal, transversely elliptical, flush, about one-third the way from the margin to the apex. Upper surface finely granulated between small tubercles; tubercles on lower surface much larger than on upper, deeply sunken in large scrobiculae except near the margin, where they are much smaller. Longitudinal median band on base moderately wide and deeply pitted.

Length, 25.4 mm.; width, 22 mm.; height, 11.3 mm.

Occurrence.—FLORIDA: Suwannee River below Troy Springs, Lafayette County (station 7347, type, C. W. Cooke, collector); Suwannee River at Dowling Springs, Suwannee County (station 7338, C. W. Cooke, collector); 5 miles northwest of Mayo on road to Dowling Park (station 11114, C. W. Cooke and Stuart Mossom, collectors); Perry road 5.2 miles west of Mayo (station 14537, C. W. Cooke, collector); east side of Steinhatchee River in Dixie County opposite Clara (station 12747, W. C. Mansfield and G. M. Ponton, collectors; station 14158, W. C. Mansfield and C. W. Mumm, collectors); 12 miles north of Marianna (station 14182, W. C. Mansfield and C. W. Mumm, collectors).

GEORGIA: Miller County about 1 mile southeast of Joe Shingler's and about 5 miles west of Colquitt (station 8247, cast of interior, C. W. Cooke, collector); Spring Creek at Colquitt (station 10168, cast of interior, C. W. Cooke and T. M. Prettyman, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Holotype, U. S. Nat. Mus. 498996.

Remarks.—*Cassidulus trojanus* is narrower than *C. alabamensis*, and its periproct is farther forward. The longitudinal profile of its upper surface is more evenly rounded than that of *C. gouldii*, which is commonly conical. Its oral lobes and phyllodes are less conspicuous than those of *C. evergladensis*, whose periproct is terminal. The specimen from station 14182 is narrower behind than others referred to this species. The available specimens indicate that *C. trojanus* did not grow as large as any of the other species mentioned.

Subgenus PARALAMPAS Duncan and Sladen, 1882

Pygorhynchus Agassiz. DESOR, *1858*, Synopsis des échinides fossiles, p. 297.
Paralampas DUNCAN and SLADEN, *1882*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, p. 72.
Plagiopygus LAMBERT, *1897*, Soc. belge géologie Bull. (Mém.), t. 11, p. 162.

Pleuropygus LAMBERT and THIÉRY in LAMBERT, *1913*, Schweizer. palaeont. Gesell. Abh., Band 39, p. 126.
Paralampas LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 371.
Anisopetalus H. L. CLARK in ARNOLD and CLARK, *1927*, Harvard College Mus. Comp. Zoology Mem., vol. 50, no. 1, p. 44.

Genotype, *Paralampas pileus* Duncan and Sladen (1882, p. 73, pl. 15, figs. 11–14), from the Eocene (Ranikot) of Sind, designated by Lambert and Thiéry (1921). Desor (1858, pl. 31, figs. 1–3) figured as representative of *Pygorhynchus* Agassiz, 1839 (genotype, *Catopygus obovatus* Agassiz, designated by Lambert and Thiéry, 1921), a specimen of *Nucleolites grignonensis* Defrance, which species later became the genotype of *Plagiopygus* and *Pleuropygus*. The genotype of *Anisopetalus* is *A. ellipticus* H. L. Clark, from Jamaica (presumably Eocene), by monotypy.

The American species here referred to *Paralampas* are Eocene. They resemble more closely the published figures of *Nucleolites grignonensis* than of *Paralampas pileus*, which species, according to Duncan and Sladen, lacks the median actinal band visible on *grignonensis* and the American species. But this lack may be merely apparent, for Duncan and Sladen's specimen appears to be rather poorly preserved. If this or other differences should eliminate *grignonensis* and the American species from *Paralampas*, they may take the name *Plagiopygus*, which is not preoccupied under the International Rules.

CASSIDULUS (PARALAMPAS) CONRADI (Conrad)

Catopygus conradi CONRAD, *1850*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 39, pl. 1, fig. 9.
Cassidulus conradi CONRAD, *1865*, idem, Proc., p. 75.
Cassidulus (*Pygorhynchus*) *conradi* CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 145, pl. 67, figs. 1a–f.
Rhyncholampas conradi LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 370.

Occurrence.—GEORGIA: Palmyra, Lee County (type, fide Conrad); Kinchafoonee Creek, 2 miles north of Albany (station 5054, T. W. Vaughan, collector; station 7121, C. W. Cooke and J. E. Brantly, collectors; station 10507, C. W. Cooke and T. M. Prettyman, collectors). Casts of the interior, probably representing this species, from Ichawaynochaway Creek about 4 miles west of Newton (station 10919, Stuart Mossom, collector); about 1 mile southeast of Joe Shingler's and 5 miles west of Colquitt (station 8247, C. W. Cooke, collector).

ALABAMA: Conecuh River 1 mile east of Harts Bridge, Covington County, in the SW. ¼ sec. 28, T. 3 N., R. 14 E. (station 10025, C. W. Cooke and Julia Gardner, collectors).

FLORIDA: Alachua (cast of the interior, station 6790, C. W. Cooke and Herman Gunter, collectors); Florida Basic Rock Company, 12 miles north of Marianna (station 12058, W. C. Mansfield and G. M. Ponton, collectors; station 14182, W. C. Mansfield and C. W. Mumm, collectors); Florida 2, 6 miles north of High Springs (Florida Geol. Survey, G. M. Ponton, collector); 1 mile north of Mayo (Florida Geol. Survey, G. M. Ponton, collector); excavation for bridge at Caryville, depth 40 feet (Florida Geol. Survey).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Acad. Nat. Sci. Philadelphia.

CASSIDULUS (PARALAMPAS) LYELLI (Conrad)

Nucleolites lyelli CONRAD, *1850*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 40, pl. 1, fig. 14.
Cassidulus lyelli CONRAD, *1865*, idem. Proc., p. 75.
Pygorhynchus lyelli COTTEAU, *1888*, Paléontologie française, Échinides éocènes, t. 1, p. 550.
Cassidulus (*Rhynchopygus*) *lyelli* CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 141, pl. 65, figs. 4a–d.
Cassidulus (*Pygorhynchus*) *georgiensis* TWITCHELL *1915*, idem, p. 170, pl. 79, figs. 2a–d.
Rhyncholampas lyelli LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 370.
Rhyncholampas georgiensis LAMBERT and THIÉRY, *1921*, idem, p. 370.

Occurrence.—GEORGIA: Baker County (type, J. H. Couper, collector); Bainbridge (station 3293, type of *C. georgiensis*, A. H. Brooks, collector; station 6171, L. W. Stephenson, collector; station 7097, C. W. Cooke and W. C. Mansfield, collectors; station 13611, A. F. Foerste, collector Red Bluff, 6 miles above Bainbridge (station 6159 L. W. Stephenson, collector); Chattahoochee River at Saffold (station 8249, H. K. Shearer, collector; station 12100, C. W. Cooke and W. H. Monroe, collectors).

FLORIDA: Chattahoochee River 5 miles below Neals Landing (station 6763, C. W. Cooke, collector); Chattahoochee River one-fourth mile below Bartons Landing (station 6765, C. W. Cooke, collector); Holder mine, 5 miles southwest of Inverness (station 7382, C. W. Cooke, collector); between Inglis and Yankeetown, Levy County (station 14544, C. W. Cooke and W. D. Havens, collectors); quarry 1½ miles west of Springfield Church, about 12 miles north of Marianna (station 14152, W. C. Mansfield and C. W. Mumm, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—A cast of the interior, probably Acad. Nat. Sci. Philadelphia. Holotype of *C. georgiensis*, U. S. Nat. Mus. 164747.

Remarks.—The specimens from Florida are higher in front than behind, thus differing from those from Bainbridge, Ga., which are uniformly inflated. This difference is probably not of specific importance, for other species show considerable variation in tumidity.

CASSIDULUS (PARALAMPAS) CAROLINENSIS (Twitchell)

Cassidulus (*Pygorhynchus*) *carolinensis* TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 146, pl. 67, figs. 2a–g.

Occurrence.—NORTH CAROLINA: Smith Creek (type); Rocky Point, Pender County (station 779, T. W. Stanton, collector); city rock quarry, Wilmington (station 3602, Frank Burns, collector; station 4285, L. W. Stephenson, collector); Castle Hayne (L. W. Stephenson, collector); 1 mile northwest of Lanes Ferry, Northeast Cape Fear River (L. W. Stephenson, collector).

FLORIDA: Quarry in Dixie County north of US 19 east of Steinhatchee River opposite Clara, (station 14541, C. W. Cooke and W. D. Havens, collectors).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—Johns Hopkins University.

Remarks.—Lambert and Thiéry (1921, p. 370) say that this species appears to be a synonym of *C. conradi*, but comparison of specimens show that they are amply distinct. The most conspicuous difference is the protracted shape of the posterior end of *conradi*. The apical system of *carolinensis* is a little nearer the center than that of *conradi*, and the poriferous zones are much wider. The specimens from Florida tend to be less concave about the peristome than the typical form.

CASSIDULUS (PARALAMPAS?) GREGORYI (Twitchell)

Breynella gregoryi TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 148, pl. 68, figs. 1a–f.

Echinanthus gregoryi LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 367.

Occurrence.—SOUTH CAROLINA: Santee Canal.

Geologic horizon.—Late Eocene, probably Santee limestone.

Type.—Am. Mus. Nat. History.

Remarks.—The figures of this species resemble *Cassidulus carolinensis* from the same horizon in North Carolina except that the periproct appears to be a little higher than wide, whereas that of *carolinensis* is wider than high. This difference may be the result of erosion of the area above the periproct. If the shape is accidental, *gregoryi* is probably a synonym of *carolinensis*.

CASSIDULUS? OVIFORMIS (Conrad)

Catopygus oviformis CONRAD, *1850*, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 39, pl. 1, fig. 15.

Nucleolites oviformis CONRAD in COOK, *1868*, Geology of New Jersey, p. 722.

Catopygus oviformis CLARK, *1893*, U. S. Geol. Bull. 97, p. 64, pl. 27, figs. 2a–f.

Catopygus oviformis CLARK, *1915*, idem, Mon. 54, p. 72, pl. 29, figs. 2a–f.

Occurrence.—NEW JERSEY: Timber Creek.

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia 1477.

This species, which I have not seen, is of uncertain generic position. It is removed from *Catopygus* by the shape of its peristome and by its lack of a conspicuous floscelle. In size and shape it resembles *Cassidulus*, but its peristome appears to be somewhat more nearly oval than late Eocene species, and its periproct is higher than wide.

Subgenus GALEROLAMPAS Cotteau, 1889

Galerolampas COTTEAU *1889*, Paléontologie française, Échinides éocènes, t. 2, p. 1.

Rhyncholampas (*Galerolampas*) LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, p. 371.

Genotype, *Galerolampas sorigneti* Cotteau (1889, p. 3, pl. 201, figs. 1–6), from the middle Eocene of France, by monotypy.

The differences between *Galerolampas* and the fossil species here referred to *Cassidulus*, s.s., are rather intangible. In general, *Galerolampas* appears to be a little more depressed above and more concave below, its periproct is more nearly terminal, and the sides of its petals are straighter. As none of these differences are of much importance, the fossil species of *Cassidulus*, s.s., might very well be transferred to *Galerolampas* if *Cassidulus caribœarum* proves to be generically distinct.

CASSIDULUS (GALEROLAMPAS) FONTIS
Cooke, n. sp.
Plate 2, figures 26–29

Test oval, upper surface moderately low, under surface slightly concave; apex eccentric anteriorly; four genital pores, five ocular pores; ambulacral areas narrow; petals narrow, nearly straight, open at the ends; anterior petal the shortest, other petals nearly equal, all extending more than halfway to the ambitus; ambulacral pores small; inner pores round, outer pores oval; pore pairs conjugate, oblique; widest part of the interporiferous areas more than twice as wide as one poriferous area; periproct terminal, at the top of a sulcus, transversely oval; peristome eccentric anteriorly, pentagonal, broader than long, with a floscelle; tubercles on under side much larger than those above.

Length, 38.7 mm.; width, 35.8 mm.; height, 16 mm.

Occurrence.—FLORIDA: Well near Falling Water 4 miles south of Chipley, depth less than 1600 feet (station 8872g, E. C. Butler, collector).

Geologic horizon.—Early Tertiary, formation unknown; probably early Eocene or Paleocene.

Type.—U. S. Nat. Mus. 498997.

Remarks.—This species, known from only one slightly crushed specimen, is similar to Cotteau's figures of *Galerolampas soriguеti*, which, however, do not show the periproct.

Genus EURHODIA d'Archiac and Haime, 1853

Eurhodia D'ARCHIAC and HAIME, *1853*, Animaux fossiles du groupe nummulitique de l'Inde, p. 214.
Eurhodia DESOR, *1858*, Synopsis des échinides fossiles, p. 300.
Ravenelia MCCRADY, *1859*, Elliot Soc. Nat. History Charleston Proc., vol. 1, p. 283.
Eurhodia DUNCAN and SLADEN, *1882*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, pp. 69, 70.
Eurhodia LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 364.

Genotype, *Pygorhynchus morrisii* d'Archiac, from the late Eocene (Ranikot) of Sind, by monotypy.

Eurhodia differs from other Eocene Cassidulidae in its deeply sunken periproct, which is wider than high, and in its longitudinally elongated pentagonal peristome.

EURHODIA RAVENELI (Twitchell)

Pygorhynchus crucifer (Morton). RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 4, figs. 9, 10.
Ravenelia crucifer (Morton). MCCRADY, *1859*, Elliot Soc. Nat. History Charleston Proc., vol. 1, p. 283.
Cassidulus (*Rhynchopygus*) *raveneli* TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 142, pl. 65, figs. 5a–d; pl. 66, figs. 1a–c, 2a–b.
Eurhodia rugosa (Ravenel). LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 365.

Occurrence.—SOUTH CAROLINA: Santee River (fide Ravenel); Santee Canal (type).
NORTH CAROLINA: Wilmington (station 3602, Frank Burns, collector; U. S. Nat. Mus. 166494, L. W. Stephenson collector; station 10340, C. W. Cooke, collector, station 10613, L. B. Kellum, collector); Sabiston's farm, 2 miles north of Jacksonville (station 10637, L. B. Kellum, collector); 1 mile northwest of Lanes Ferry, Northeast Cape Fear River (U. S. Nat. Mus. 166493, L. W. Stephenson, collector).

Geologic horizon.—Late Eocene, Santee limestone (South Carolina); Castle Hayne marl (North Carolina).

Type.—Am. Mus. Nat. History.

Remarks.—Lambert and Thiéry regard this species as the adult form of the species figured by Ravenel (1848, p. 4, figs. 7, 8) under the name *Pygorhynchus rugosus*. This may be true, but the type of *rugosus* is lost, no specific locality nor description is given, and the figure differs notably from specimens of comparable size. It seems better to accept Twitchell's species and to discard *Pygorhynchus rugosus* as unrecognizable.

EURHODIA PATELLIFORMIS (Bouvé)
Plate 5, figures 1–4

Catopygus patelliformis BOUVÉ, *1851*, Boston Soc. Nat. History Proc., vol. 4, p. 2, 2 text figs.
Cassidulus patelliformis DESOR, *1858*, Synopsis des échinides fossiles, p. 290.
Cassidulus (*Rhynchopygus?*) *patelliformis* CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 143, pl. 66, figs. 3a–d.
Cassidulus (*Rhynchopygus*) *depressus* TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 144, pl. 66, figs. 4a–e, 5a–b. Not *Gisopygus depressus* Fourtau, 1908, p. 136, pl. 8, figs. 15, 16.
Procassidulus patelliformis LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 362.
Procassidulus depressus LAMBERT and THÉRY, *1921*, idem, p. 362.

Occurrence.—GEORGIA: Baker County (type of *C. depressus*); Albany (station 5054, figured, T. W. Vaughan, collector; station 7121, C. W. Cooke, collector).

ALABAMA: Conecuh River 1 mile east of Harts Bridge (station 10025, C. W. Cooke and Julia Gardner, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Holotype, Boston Soc. Nat. History 1558. Holotype of *Cassidulus depressus* Twitchell, Boston Soc. Nat. History 1557a. Deposited in Mus. Comp. Zoology, Cambridge, Mass.

Remarks.—This species is characterized by its unusually flat bottom and by its small, deeply sunken periproct. Though the holotype is much higher than other specimens referred to this species, there is little doubt that *Cassidulus depressus* Twitchell is a synonym, for such variation in shape is common among the Cassidulidae. The figured specimen is intermediate in size between Bouvé's and Twitchell's types. Twitchell's specific name appears to be preoccupied by *Eurhodia depressa* (Fourtau).

EURHODIA HOLMESI (Twitchell)

Cassidulus (*Rhynchopygus?*) *holmesi* TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 140, pl. 65, figs. 3a–d.

Rhyncholampas holmesi LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 370.

Cassidulus (*Pygorhynchus*) *carolinensis* var *cravenensis* KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 15, pl. 1, figs. 1–3.

Occurrence.—SOUTH CAROLINA: Santee River (?) (type); Cave Hall, Santee River scarp 6 miles northeast of Elloree (station 4856, Earle Sloan and T. W. Vaughan, collectors).

NORTH CAROLINA: Pitt County 3 miles east of Quinerly and 2 miles north of the Neuse River (station 10627, type of *cravenensis*, L. B. Kellum, collector); J. A. Stokes' farm, Craven County 2 miles north of Maple Cypress (station 8165, J. A. Cushman, collector); Biddle Landing, Neuse River, north of Ft. Barnwell, Craven County (station 10626, L. B. Kellum, collector); Douglas Green's farm 1 mile west of Maple Cypress (station 12007, W. C. Mansfield, collector).

Geologic horizon.—Late Eocene, Santee limestone (South Carolina) and Castle Hayne marl (North Carolina).

Type.—Holotype, F. S. Holmes collection, Am. Mus. Nat. History. Type of *cravenensis*, U. S. Nat. Mus. 353256.

Remarks.—The three specimens from Cave Hall agree well with figures of the holotype, which is without specific locality. Those from North Carolina, of which there is a large suite, are somewhat less rostrate behind and have smaller peristomes. Perhaps Kellum's name *cravenensis* should be retained to designate the variety. One of the specimens from Cave Hall has an abnormal, apparently twisted peristome.

EURHODIA? ELBANA Cooke, n. sp.
Plate 5, figures 5–8

Test small, subquadrate; upper surface moderately tumid, lower surface slightly concave; margin rounded; tubercles larger on lower than on upper surface. Apical system eccentric anteriorly. Paired petals open at the distal ends; anterior pairs widely divergent; pore pairs oblique; pores conjugate. Peristome pentagonal, equilateral, anteriorly eccentric; oral lobes rounded. Periproct small, transversely oval, nearly round, supramarginal, within a short tube that merges into a posterior sulcus.

Length, 20 mm.; width, 16 mm.; height, 9.5 mm.

Occurrence.—ALABAMA: Pea River at power plant 4 miles below Elba (station 10013, C. W. Cooke and Julia Gardner, collectors).

EXPLANATION OF PLATE 5

All figures ×1

FIGS. *1–4*—*Eurhodia patelliformis* (Bouvé). U. S. Nat. Mus. 498988, Albany, Ga. Late Eocene. (p. 35)

5–8—*Eurhodia? elbana* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498981, power plant on Pea River below Elba, Ala. Early Eocene. (p. 36)

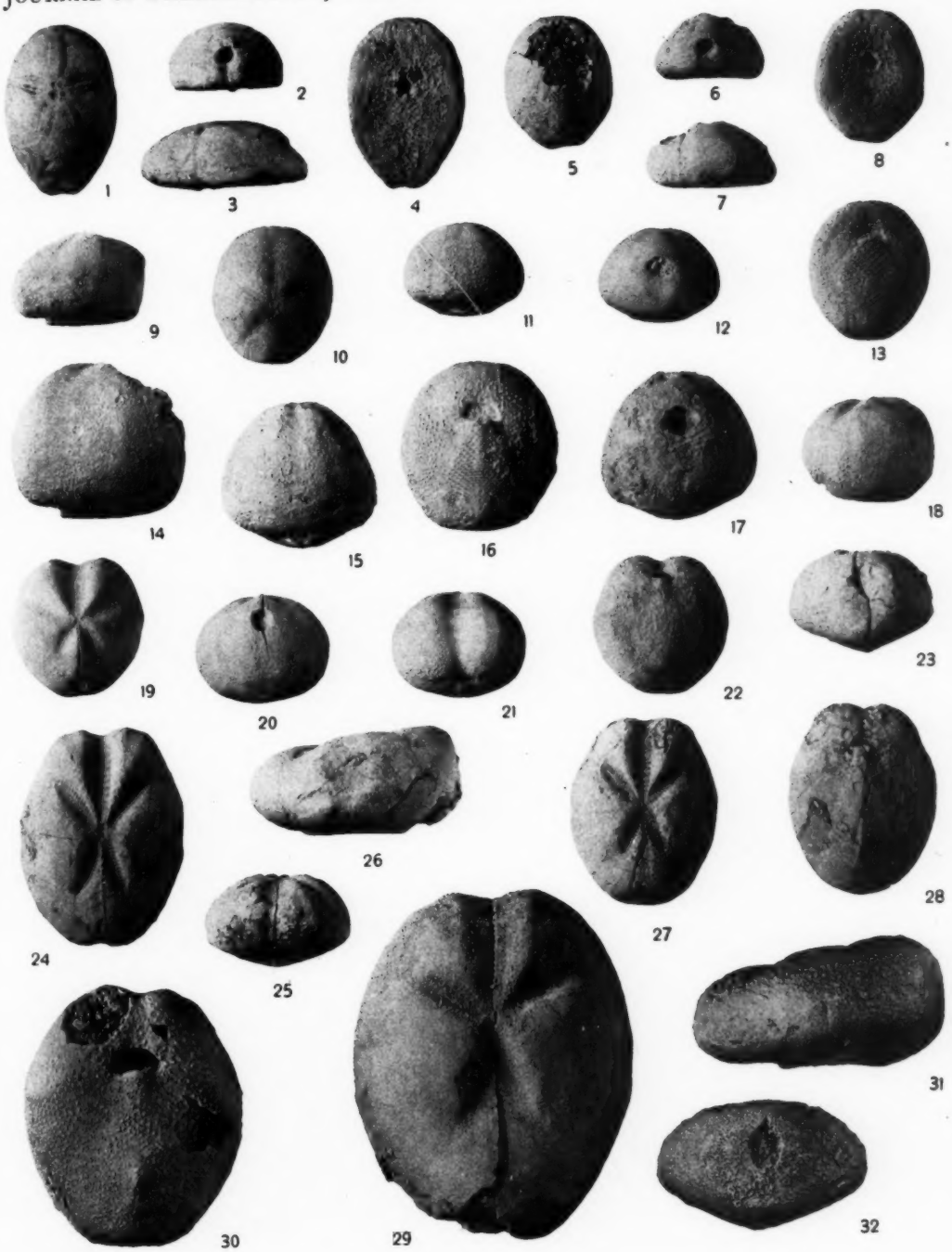
9–13—*Agassizia* (*Anisaster*) *wilmingtonica* Cooke, n. sp. Holotype, U. S. Nat. Mus. 499004, Wilmington, N. C. Late Eocene. (p. 46)

14–17—*Agassizia* (*Anisaster*) *mossomi* Cooke, n. sp. *14*, *15*, Holotype; *16*, *17*, paratype; U. S. Nat. Mus. 498989; Brooksville, Fla. Late Oligocene. (p. 46)

18–22—*Schizaster* (*Linthia*) *ocalanus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498990, Kendrick, Fla. Late Eocene. (p. 42)

23–28—*Brissopsis blanpiedi* Grant and Hertlein. Two topotypes, U. S. Nat. Mus. 498998, Lemon, Smith County, Miss. Middle Oligocene. (p. 49)

29–32—*Brissopsis steinhatchee* Cooke, n. sp. *29*, Holotype; *30–32*, a paratype; U. S. Nat. Mus. 498987, Steinhatchee River near Clara, Fla. Late Eocene. (p. 49)



Cooke, Cenozoic Echinoids

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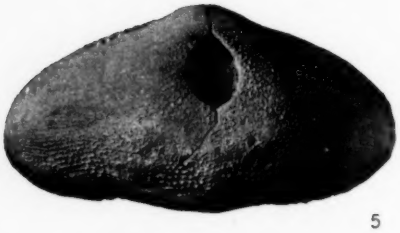

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Cooke, Cenozoic Echinoids

Geologic horizon.—Early Eocene, Wilcox group, Bashi formation.

Type.—U. S. Nat. Mus. 498981.

Remarks.—This species is represented by a single individual, from which the apex and part of the petals are missing. It does not closely resemble any other known American species. Its periproct suggests that of *Eurhodia patelliformis* (Bouvé), but its test is broader, its peristome is not elongated, and its margin is not so sharp. Its equilateral peristome distinguishes it from other species of *Eurhodia*. In general appearance it resembles *Cassidulus* (*Paralampas*) *carolinensis* Twitchell, but its periproct is farther forward and more deeply sunken, and its margin is less broadly rounded.

Genus ECHANTHUS Cooke, n. gen.

Echinanthus DESOR, *1858*, Synopsis des échinides fossiles, p. 291. Not Leske, 1778.
Echinanthus DUNCAN and SLADEN, *1882*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, p. 12.
Echinanthus POMEL, *1883*, Classification méthodique et genera des échinides, p. 61.
Echinanthus COTTEAU, *1888*, Paléontologie française, Échinides éocènes, t. 1, p. 553.

Test subpentagonal. Apex eccentric anteriorly, with a large central madreporite, four genital pores, and five ocular pores. Petals spatulate, open at the ends, posterior pair longer than the others, poriferous zones of each petal of equal length, pore pairs oblique, pores nearly equal; extrapetalous pores single; floscelle well developed. Under surface slightly concave, with a narrow longitudinal granulated band not raised or callous and lacking large scrobiculae. Peristome eccentric anteriorly, beneath the apex, pentagonal; phyllodes short, broad, conspicuous; oral lobes inflated. Periproct terminal, higher than wide, oval, sunken, at the top of a marginal furrow.

Genotype, *Echinanthus georgiensis* Twitchell, from the Paleocene Clayton formation of Georgia and Alabama.

Echanthus appears to be synonymous with *Echinanthus* Desor (not Leske), whose genotype is *Clypeaster cuvieri* Münster (Desor, 1858, p. 292, pl. 34, figs. 17, 18) which is quite different from any of the species referred by Leske to *Echinanthus*. Desor attributed the genus to Breynius, 1732, who was pre-Linnean. Gregory (1892, p. 600) proposed *Breynella* to include species commonly known as *Echinanthus*, but the only two species cited appear to represent *Echinolampas*, which has an oblique, flush periproct in contrast to the vertical, sunken periproct of *Echanthus*. *Echanthus* differs from *Parapygus* Pomel (1883, p. 61), genotype *Botriopygus toucasanus* d'Orbigny (1855, p. 340, pl. 931), in its sunken periproct and in its outer ambulacral pores, which are nearly round, not slotlike.

ECHANTHUS GEORGIENSIS (Twitchell)
Plate 8, figures 1–3

Echinanthus georgiensis TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 139, pl. 65, figs. 1a–d.

Occurrence.—GEORGIA: Dr. A. J. Parker's farm, Ellaville-Americus road 5 miles south of Ellaville (station 4033, S. W. McCallie, collector, type).

ALABAMA: Luverne road 4.6 miles south of Highland Home, Crenshaw County (station 10497, L. W. Stephenson, collector, casts of the interior); 5 miles south of Highland Home on Alabama 9 in SE. ¼ sec. 25, T. 11 N., R. 17 E., (station 14920, C. W. Cooke and A. C. Munyan, collectors, casts of the interior); chert blocks near road in sec. 21, T. 10 N., R. 28 E., Barbour County, 2¼ miles east of Cotton Hill (station 10910, C. W. Cooke, collector, casts of the interior).

Geologic horizon.—Paleocene, Clayton formation.

Type.—U. S. Nat. Mus. 165683*b*.

Family ECHINOLAMPADIDAE Bernard, 1895

Genus ECHINOLAMPAS Gray, 1825

Echinolampas GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 429.
Echinolampas D'ARCHIAC and HAIME, *1853*, Ani-

EXPLANATION OF PLATE 6
All figures ×1

FIGS. *1–3*—*Eupatagus* (*Plagiobrissus*) *dixie* Cooke, n. sp. *1*, Paratype, U. S. Nat. Mus. 498986, Steinhatchee River near Clara, Fla.; *2*, *3*, holotype, U. S. Nat. Mus. 498985, 1 mile north of Mayo, Fla. Late Eocene. (p. 55)

4–8—*Eupatagus* (*Plagiobrissus*) *ocalanus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 372984, 1 mile north of Mayo, Fla. Late Eocene. (p. 57)

maux fossiles du groupe nummultique de l'Inde, p. 209.
Echinolampas A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 335.
Echinolampas POMEL, *1883*, Classification méthodique et genera des échinides, p. 62.
Echinolampas COTTEAU, *1889*, Paléontologie française, Échinides éocènes, t. 2, p. 5.
Breynella GREGORY, *1892*, Roy. Soc. Edinburgh Trans., vol. 36, p. 600.
Echinolampas H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 111.
Echinolampas LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, p. 377.

Genotype, *Echinus oviformis* Gmelin, 1788, = *Echinanthus ovatus* Leske (1778, p. 191, pl. 20, figs. *c*, *d*), living in the Indian Ocean, designated by Pomel, 1883. The genotype of *Breynella* is *Pygorhynchus vasalli* Wright, 1855, from the Miocene of Malta, here designated. Gregory intended *Breynella* as a substitute for *Echinanthus* of authors (*Echanthus* Cooke, n. gen.), but the only two species named appear to represent *Echinolampas*.

ECHINOLAMPAS APPENDICULATA Emmons

Echinolampas appendiculatus EMMONS, *1858*, Agriculture of the eastern counties, p. 307, figs. 240, 241.
Echinolampas appendiculatus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 149, pl. 68, figs. 2a–h.
Echinolampas (*Isolampas*) *appendiculatus* LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 380, 1921.
Echinolampas (*Miolampas*) *appendiculata* LAMBERT and THIÉRY, *1921*, idem, p. 382.

Occurrence.—NORTH CAROLINA: Newbern; Rocky Point (station 779, T. W. Stanton, collector); Wilmington (station 782, Smith Creek, T. W. Stanton, collector; stations 4285, 4287, L. W. Stephenson, collector; 3602, Frank Burns, collector; L. W. Stephenson, E. W. Berry, and B. L. Miller, collectors); Castle Hayne (station 4286, L. W. Stephenson, collector); Lane's Ferry on Northeast Cape Fear River 3 miles east of Rocky Point (L. W. Stephenson, collector); 1 mile northwest of Lane's Ferry (L. W. Stephenson, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—U. S. Nat. Mus. 499113, deposited by Williams College.

ECHINOLAMPAS ALDRICHI Twitchell

Echinolampas aldrichi TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 173, pl. 81, figs. 1a–d, 2.
Echinolampas (*Miolampas*) *aldrichi* LAMBERT and THIÉRY, *1921*, Nomenclature raisonnée des échinides, fasc. 5, p. 383.

Occurrence.—ALABAMA: Bluff east of Jackson-Rockville road 200 yards north of Salt Creek, Clark County, NW. ¼ sec. 34, T. 6 N., R. 2 E. (station 7165, C. W. Cooke, collector); 1 mile north of Glendon, Clarke County, NW. ¼ sec. 31, T. 7 N., R. 3 E. (station 7163, C. W. Cooke, collector); ½ mile northwest of Glendon (station 14514, F. S. MacNeil, collector); Perdue Hill, Monroe County (station 2398, Frank Burns, collector); road to Lambard's Landing, 1.7 miles southeast of Gainestown, Clarke County (station 10050, C. W. Cooke and Julia Gardner, collectors); Gainestown Ferry, Clarke County (station 10052, C. W. Cooke and Julia Gardner, collectors); Choctaw Bluff, Alabama River (Univ. Alabama); 1.3 miles north of Millry, Washington County (station 14291, W. C. Mansfield, collector).

MISSISSIPPI: Four miles north of Waynesboro on road to Shubuta, near middle of sec. 24, T. 9 N., R. 7 W. (station 10053, C. W. Cooke and Julia Gardner, collectors); Taylor Mill Creek 1½ miles north of Waynesboro (stations 14281a, W. C. Mansfield and F. S. MacNeil, collectors; 14347, Julia Gardner, collector); Sandy Creek, Wayne County (station 14345, Julia Gardner, collector); west bank Chickasawhay River downstream from the Waynesboro-Laurel road (stations 14348, bed 2 of section; 14362, bed 4; 14350, bed 7, Julia Gardner, collector; station 14517, W. C. Mansfield and F. S. MacNeil, collectors).

Geologic horizon.—Late Oligocene, Chickasawhay marl.

Type.—Johns Hopkins University T 1099 A.

Family ECHINOCORYTHIDAE Gregory, 1900

Genus ECHINOCORYS Leske, 1778

Echinocorys LESKE, 1778, Naturalis dispositio echinodermatum, p. 175.
Anachytes LAMARCK, *1801*, Animaux sans vertèbres, p. 347.
Echinocorys D'ORBIGNY, *1853*, Paléontologie française, Terrain crétacé, t. 6, p. 58.
Ananchytes DESOR, *1858*, Synopsis des échinides fossiles, p. 329.
Ananchytes JACKSON in ZITTEL, *1913*, Text-book of paleontology, p. 292.
Echinocorys LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 417.

Genotype, *Echinocorys scutatus* Leske (1778, p. 175, pl. 15, figs. A, B), by monotypy. This species is described and figured by Desor (1858, p. 330, pl. 38, fig. 6) under the name *Ananchytes ovata* Lamarck and by d'Orbigny (1853, p. 62, pls. 804–806; 808, figs. 1–3) under the name *Echinocorys vulgaris* Breynius.

ECHINOCORYS OVALIS (Clark)

Ananchytes ovalis CLARK, *1893*, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.
Ananchytes ovalis CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 81, pl. 35, figs. 1a–h. Includes additional synonymy.

Occurrence.—NEW JERSEY: Vincentown.

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Johns Hopkins Univ. T 3011.

Family HEMIASTERIDAE
H. L. Clark, 1917

Genus SCHIZASTER Agassiz, 1836

Schizaster (part) AGASSIZ, *1836*, Soc. sci. nat. Neuchatel Mem., t. 1, p. 185.
Schizaster AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, p. 15.
Schyzaster SISMONDA, *1843*, Memoria geo-zoologica sugli echinidi fossili del contado di Nizza, p. 30.
Schizaster AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes (reprint), p. 126.
Schizaster DESOR, *1858*, Synopsis des échinides fossiles, p. 389.
Paraster POMEL, *1869*, Revue des échinodermes, p. 14.
Schizaster COTTEAU, *1875*, K. svenska vetensk. akad. Handl., Bandet 13, no. 6, p. 28.
Paraster POMEL, *1883*, Classification méthodique et genera des échinides, p. 36.
Schizaster COTTEAU, *1886*, Paléontologie française Échinides éocènes, p. 270.
Schizaster (*Paraster*) MORTENSEN, *1907*, Danish Ingolf-Expedition, vol. 4, pt. 2. Echinoidea, p. 123.
Schizaster H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 192.
Paraster JACKSON, 1922, Carnegie Inst. Washington Pub. 306, p. 74.
Schizaster GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Mat. and Phys. Sci., vol. 2, p. 119.

Genotype, *Schizaster studeri* Agassiz (1836, p. 185), from the late Eocene of Italy, by elimination. Agassiz named only two species, *Spatangus atropos* Lamarck, which became the genotype of *Moera* Michelin, 1855, = *Moira* A. Agassiz, 1872, and *Schizaster studeri*, for which the generic diagnosis should be accepted as the specific description (see H. L. Clark, 1917, p. 192, and Mortensen, 1932, p. 360). *Schizaster studeri* has been figured by Sismonda (1843, p. 32, pl. 2, fig. 4) and by Cotteau (1886, p. 344, pls. 103–105), whose plate 104, figures 4, 5, represent a plastotype. According to Cotteau this species apparently has four genital pores, whereas *Moira atropos* has two.

Pomel, supposing that *Schizaster* normally has only two genital pores, erected the genus *Paraster* (genotype *Schizaster gibberula* Agassiz and Desor, a living Red Sea species) for species having four genital pores. *Paraster* therefore becomes a synonym of *Schizaster* unless *Schizaster gibberula* has other generic differences from *S. studeri*.

Of the American species, *S. armiger* Clark and *S. americana* Clark have four genital pores, the anterior pair being so near the posterior pair that they might be mistaken for oculars; but *S. beckeri* Cooke, n. sp., has only two, the anterior pair being wanting. The same difference occurs in the subgenus *Linthia*, *L. alabamensis* Clark, *L. hanoverensis* Kellum, and *L. wilmingtonensis* Clark having four pores, whereas *L. ocalana* Cooke, n. sp., has two. All of the species named have the same complement of fascioles—a peripetalous fasciole connected with lateral fascioles that join beneath the periproct. It seems, therefore, that the number of genital pores in *Schizaster* is a specific rather than a generic feature.

SCHIZASTER ARMIGER Clark

——HARRIS, *1894*, Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, p. 172, pl. 6, fig. 11.
Schizaster armiger CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 152, pl. 70, figs. 1a–d.
Schizaster floridanus CLARK, *1915*, idem, p. 175, pl. 82, figs. 1a–c.
Schizaster armiger LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 524.

Occurrence.—ALABAMA: Near old Cocoa post post office, Choctaw County, in SW. ¼ sec. 13, T. 11 N., R. 5 W. (station 2637, type, Charles Schuchert, collector; station 7219, C. W. Cooke and W. C. Mansfield, collectors); near Fail, Choctaw County (station 2869, Charles Schuchert, collector); railroad 2 to 3 miles southeast of Whatley, Clarke County (station 2957, Frank Burns, collector); E. ½ sec. 34, T. 8 N., R. 3 E., 5 miles southeast of Whatley (station 7159, C. W. Cooke, collector); sec. 35, T. 8 N., R. 3 E., 500 feet east of Jones' Field Branch, 5 miles southeast of Whatley (station 7161, C. W. Cooke, collector); 2½ miles northeast of Jackson (station 3642, T. W. Vaughan, collector); Claiborne (station 5567, bed 8, T. W. Vaughan, collector; station 10023, 8 feet above the "Scutella" bed, C. W. Cooke, collector; station 12166, C. W. Cooke and R. B. Stewart, collectors; Alabama Geol. Survey, W. McGlamery, collector); Claiborne road west of Double Branches, 2½ miles southwest of Monroe-

ville (station 6730, C. W. Cooke, collector); 1½ miles southwest of Perdue Hill (station 10043, C. W. Cooke and Julia Gardner, collectors); Tombigbee River ¾ mile above St. Stephens Bluff, 10 feet above the Moodys marl (station 7392, C. W. Cooke, collector).

MISSISSIPPI: Railroad cut southwest of the pumping station at Jackson (station 12172, C. W. Cooke, R. B. Stewart, and W. H. Monroe, collectors).

GEORGIA: Power plant on Kinchafoonee Creek 2 miles north of Albany (station 7121, C. W. Cooke and J. E. Brantly, collectors); Flint River in the northeast corner of Dougherty County (station 7235, C. W. Cooke, collector).

FLORIDA: Johnson's Sink, Levy County (station 365, type of *Schizaster floridanus*, L. C. Johnson, collector); Suwannee River 17 miles south of Ellaville (station 2612, G. H. Eldridge, collector); Suwannee River 100 yards below Troy Springs, 6 miles northwest of Branford (station 7347, C. W. Cooke, collector); lowest bed at mouth of Withlacoochee River at Ellaville (station 11111, C. W. Cooke and Stuart Mossom, collectors); 5 miles northwest of Mayo on road to Dowling Park (station 11114, C. W. Cooke and Stuart Mossom, collectors); Steinhatchee River opposite Clara, Dixie County (station 12747, W. C. Mansfield and G. M. Ponton, collectors; station 14541, C. W. Cooke and W. D. Havens, collectors); 1 mile north of Mayo (Florida Geological Survey, G. M. Ponton, collector); Daysville, between Gainesville and Archer (R. B. Becker, collector); Crystal River Rock Company, 6 miles southeast of Crystal River (station 14336, C. W. Cooke and F. S. MacNeil, collectors).

ARKANSAS: East bank Sabine River at Cornish Ferry (Caveness Landing) about 5 miles east-northeast of Warren, Bradley County (station 2412, G. D. Harris, collector).

Geologic horizon.—Late Eocene, Jackson formation and Ocala limestone.

Type.—U. S. Nat. Mus. 141104.

Remarks.—*Schizaster armiger* is very difficult to distinguish from *S. americanus;* but its posterior petals are proportionately longer than those of *P. americanus*, its peripetalous fasciole is angular, not rounded, between the lateral petals and crosses the interambulacral area nearer the center.

SCHIZASTER BECKERI Cooke, n. sp.
Plate 3, figures 5–8

Test tumid above and below, margin rounded, highest behind the center, sloping steeply forward, vertically truncated behind. Apical system behind the center, with two posterior genital pores. Anterior ambulacral area deeply depressed halfway to the margin, thence becoming shallower, but depression still perceptible at the peristome. Petals deeply depressed; anterior pair long, with nearly straight margins, slightly curved outwards at the tip; posterior pair depressed, much shorter; interporiferous zones about as wide as poriferous zones; pores elongate-oval, conjugate. Peristome fairly large, curved, with a strongly rostrate posterior lip; near the anterior end. Periproct oval, higher than wide, high up on the posterior end. Peripetalous fasciole deeply indented between the lateral petals.

Length, 28 mm.; width, 25 mm.; height, 22 mm.

Occurrence.—FLORIDA: Gainesville rock pit southeast of Arredondo, Alachua County (type, R. B. Becker, collector); Suwannee River at bridge near Dowling Park, in Lafayette County (paratype, station 14553, C. W. Cooke, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 499008; paratype, 499009.

Remarks.—*Schizaster beckeri* is higher and more rotund than other species of *Schizaster* s.s. from the United States. Moreover, it has only two genital pores rather than four.

SCHIZASTER AMERICANUS Clark

Schizaster americana CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 176, pl. 82, figs. 2a–d.

Schizaster americanus LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 526.

Occurrence.—MISSISSIPPI: Yost's lime kiln near Brandon (type, station 3951, A. F. Crider, collector); Vicksburg (A. H. Worthen, collector; station 6450, from ledges forming waterfall at Mint Spring Bayou, C. W. Cooke and E. N. Lowe, collectors); Sylvarena road about 4½ miles west of Bay Springs (station 7374, E. N. Lowe and C. W. Cooke, collectors); Panther Creek, 7 miles north of Youngton, Warren County, in sec. 22 (station 7447, O. B. Hopkins, collector).

ALABAMA: A fragment, probably this species, at Jay Branch, sec. 15, T. 5 N., R. 5 E., Monroe County (station 14368, C. W. Cooke, Julia Gardner, and Edgar Bowles, collectors).

GEORGIA: Ocmulgee River at mill ¾ mile below Hawkinsville (station 10482, H. S. Cave, collector).

Geologic horizon.—Middle and late Oligocene: Byram formation (Mississippi); Bucatunna clay member of Byram (Alabama); Suwanne limestone (Georgia).

Type.—U. S. Nat. Mus. 165695.

Remarks.—*Schizaster americanus* closely resembles *S. armiger*, but its posterior

petals are proportionately shorter, and its peripetalous fasciole is less deeply reentrant between the lateral petals and crosses the anterior ambulacral area nearer the margin.

SCHIZASTER sp. a

Internal casts from the Lisbon formation of Mississippi resemble *Schizaster armiger* Clark except that they are considerably lower than undistorted individuals of that species.

Occurrence.—MISSISSIPPI: Wautubbee Hills, railroad cut 4 miles south of Enterprise, between mile posts 20 and 21 south of Meridian (station 2616, Frank Burns, collector; station 6479, E. N. Lowe and C. W. Cooke, collectors); bridge over Falling Creek on road to Langsdale, 6 miles south of Quitman (station 6482, C. W. Cooke, collector).

Geologic horizon.—Middle Eocene, Lisbon formation (Wautubbee marl of Lowe).

SCHIZASTER sp. b

Casts from three widely separated places but probably from the same horizon appear to represent an undescribed species of *Schizaster*. Its apical system is farther back than that of *S. americana*, its anterior paired petals are less diverging, its posterior petals are somewhat shorter, and it is more sharply pointed behind.

Occurrence.—ALABAMA: Old Weaver Chute, 2 or 3 miles below McGowans Bridge, Escambia County (station 6753, C. W. Cooke, collector, cast made from a mold of the exterior); clay squeezes made from a siliceous mold owned by a country potter, reported to have been found near Baker Hill, Barbour County (station 10778, C. W. Cooke and W. S. Hoffmeister, collectors).

FLORIDA: West side S. ½ sec. 25, T. 7 N., R. 17 W., ¾ mile south of the Alabama State line in Holmes County (station 15101, C. W. Cooke, collector, natural cast of the interior).

Geologic horizon.—Late Oligocene, Chickasawhay marl and Flint River formation.

Subgenus LINTHIA Desor, 1853

Linthia DESOR, *1853*, Soc. helvetique sci. nat. Actes (Porrentruy) (Schweitzer. naturf. Gesell. Verh.), p. 278.
Linthia DESOR, *1858*, Synopsis des échinides fossiles, p. 395.
Linthia A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 604.
Linthia DUNCAN and SLADEN, *1882*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, p. 17.
Linthia POMEL, *1883*, Classification méthodique et genera des échinides, p. 36.
Linthia COTTEAU, *1886*, Paléontologie française, Échinides éocènes, p. 206.
Linthia LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides. fasc. 8, p. 518.
Linthia GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 124.

Genotype, *Escheria insignis* Merian, 1853, from the middle Eocene of Switzerland, designated by Desor (1858, p. 395). This species has been figured by Desor (1858, pl. 43, fig. 9) and by Cotteau (1886, p. 232, pl. 70). Its apical system is farther forward than that of typical *Schizaster*, its petals are straighter and less deeply impressed, the posterior pair are longer, and the posterior end is less strongly rostrate. The genotypes of *Linthia* and *Schizaster* are so different in appearance that one might be justified in deeming them different genera if they alone were to be considered; but several species seem to be intermediate between the two end forms.

SCHIZASTER (LINTHIA) TUMIDULUS (Clark)

Linthia tumidula CLARK, *1891*, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 77.
Linthia tumidula CLARK, *1893*, idem, vol. 12, no. 103, p. 52.
Linthia tumidula CLARK, *1893*, U. S. Geol. Survey Bull. 97, p. 91, pl. 1, figs. 1a–i.
Linthia tumidula WELLER, *1907*, New Jersey Geol. Survey, Paleontology, vol. 4, p. 304, pl. 18, figs. 1–9.
Linthia tumidula CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 99, pl. 53, figs. 1a–i.

Occurrence.—NEW JERSEY: Timber Creek and Vincentown (Clark).

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Am. Mus. Nat. History.

Remarks.—There are no identified specimens of this species in the United States National Museum. Clark's drawings indicate that the fasciole is not at all U-shaped below the periproct in contrast with typical *Schizaster*. The petals appear to resemble those of typical *Linthia*.

SCHIZASTER (LINTHIA) WILMINGTONENSIS (Clark)

Linthia wilmingtonensis CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 152, pl. 70, figs. 3a–c.
Linthia wilmingtonensis LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 519.

Occurrence.—NORTH CAROLINA: Wilmington

(type); Rocky Point (station 779, T. W. Stanton, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—U. S. Nat. Mus. 166482.

Remarks.—The petals of this species seem to be more deeply sunken than those of typical *Linthia*, and the posterior pair show a tendency to curve backward and are shorter. The nearly central apical system and the widely spreading, nearly straight anterior pair of petals separate it from typical *Schizaster*.

SCHIZASTER (LINTHIA) HANOVERENSIS (Kellum)

Linthia hanoverensis KELLUM, *1926*, U. S. Geol. Survey Prof. Paper 143, p. 15, pl. 1, figs. 8–9, 1926.

Occurrence.—NORTH CAROLINA: Wilmington (type, station 782, T. W. Stanton, collector; L. B. Kellum, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—U. S. Nat. Mus. 164664.

Remarks.—The anterior ambulacral area of this species is less deeply depressed than is usual for *Linthia*, but the species has peripetalous and lateral fascioles. *Linthia wilmingtonensis* superficially resembles *Macropneustes carolinensis* Clark, which occupies the same geologic horizon at Wilmington, but its front and back pairs of genital pores are closer together, its anterior end is less rounded, and its peristome is farther forward than that of *Macropneustes carolinensis*, which species appears to have only a nearly straight marginal fasciole.

SCHIZASTER (LINTHIA) ALABAMENSIS (Clark)

Linthia alabamensis CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 153, pl. 71, figs. 1a–d, 2a–d.
Linthia maverickensis GARDNER, *1935*, Texas Univ. Bull. 3301, p. 110, pl. 4, figs. 13, 14.

Occurrence.—ALABAMA: Prairie Creek, Wilcox County (type, station 264, L. C. Johnson, collector); Brundidge, Pike County (Johns Hopkins Univ., T. H. Aldrich, collector).

ARKANSAS: Railroad cut ½ mile southwest of Grand Glaise, Jackson County (U. S. Nat. Mus. 166483, L. W. Stephenson, collector).

TEXAS: Indio Ranch, 6 miles below the McFarland sheep pens on the Windmill (Jacal) ranch road (station 11754, Julia Gardner, collector).

Geologic horizon.—Paleocene; Clayton formation in Alabama, Midway formation in Arkansas, and Wills Point (?) formation in Texas.

Types.—Holotype, U. S. Nat. Mus. 137371; paratype, 166483. Holotype of *maverickensis*, U. S. Nat. Mus. 370904.

Remarks.—This species is represented in the United States National Museum only by the three types specified. The type of *Linthia maverickensis* is a small internal cast that can not be certainly identified. *Linthia alabamensis* is similar to *L. varibilis* Slocum from the Upper Cretaceous Ripley formation of Mississippi, but its apical system is more nearly central, its test is not so high, and its posterior truncation is not quite so steep.

SCHIZASTER (LINTHIA) OCALANUS Cooke, n. sp.
Plate 5, figures 18–22

Test subglobular, cordate, the anterior depression extending from the apical system to the peristome, the upper surface more inflated than the lower. Apical system nearly central, with two large genital pores, one between the ends of each lateral pair of petals, and the madreporite extending behind them. Anterior ambulacral area moderately sunken; pores of each pair separated by a high granule. Petals nearly straight, sunken; anterior pair diverging at an angle of approximately 120°, the posterior at an angle of approximately 60°; anterior pair about twice as long as posterior; open at the distal ends; poriferous zones about as wide as interporiferous zones; pores conjugate. Peripetalous fasciole concave between the lateral petals, convex elsewhere. Peristome far forward, subtrigonal to subpentagonal, strongly lipped posteriorly, weakly lobate anterolaterally. Periproct about as large as the peristome, elliptical, higher than wide, high up on the flattened, sloping posterior end. Surface covered with small tubercles.

Length of holotype, 21 mm.; width, 21 mm.; height, 16 mm. Length of a paratype from station 14539, 33mm.; width, 32 mm.; height, 27 mm.

Occurrence.—FLORIDA: Pit of the Ocala Limerock Company near Kendrick (holotype, station 13429, T. H. Hubbell, collector); pit of Cummer Lumber Company near Kendrick, 4.8 miles north

of Ocala (station 12754a, C. W. Cooke and T. P. Kirby, collectors); old MacDonald quarry 1 mile north of Istachatta (figured paratype, station 11112, C. W. Cooke and Stuart Mossom, collectors); Oakhurst Lime Company, 2½ miles southeast of Ocala (station 11749, C. W. Cooke and Stuart Mossom, collectors); spoil bank of drainage canal on U. S. 19, 5 miles south of Salem, Taylor County (station 14539, C. W. Cooke and W. D. Havens, collectors); quarry 6 miles southeast of Crystal River (station 14141, W. C. Mansfield and C. W. Mumm, collectors; Florida Geol. Survey, Frank Westendick, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 498990.

Remarks.—*Schizaster* (*Linthia*) *ocalanus* is more globular than most American Linthias, and its periproct is visible from above. Moreover, it has two instead of four genital pores.

Genus MOIRA A. Agassiz, 1872

Moera MICHELIN, *1855*, Revue et magazin de zoologie, ser. 2, t. 7, p. 246. Not Huebner, 1819.
Moira A. AGASSIZ, *1872*, *1874*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 146, 365.
Moira POMEL, *1883*, Classification méthodique et genera des échinides, p. 37.
Moira H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 195.
Moira LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 532.

Genotype, *Spatangus atropos* Lamarck, living off the coast of the United States from North Carolina to Texas, by monotypy. Strict application of the rules might make this species the type of *Schizaster*, but a large group of echinologists have recommended (Mortensen, 1932, p. 360) that the present classification be retained.

MOIRA ATROPOS (Lamarck)

Spatangus atropos LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, vol. 3, p. 32.
Moira atropos A. AGASSIZ, *1874*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pt. 2, p. 365, pl. 23.
Moira atropos H. L. CLARK, *1917*, idem, vol. 46, no. 2, p. 196.

Occurrence.—Coast of the southeastern States from North Carolina to Texas; rare in the West Indies (H. L. Clark).

Geologic horizon.—Recent.

Remarks.—This species is characterized by the roofing over of part of the ambulacral depressions by expansions of the interambulacra.

Genus HEMIASTER Desor, 1847

Hemiaster DESOR in AGASSIZ and DESOR, *1847*, Annales sci. nat. (zoologie), t. 8, p. 16 (reprint, p. 122).
Hemiaster D'ORBIGNY, *1853*, Paléontologie française, Terrain crétacé, t. 6, p. 220.
Hemiaster DESOR, *1858*, Synopsis des échinides fossiles, p. 367.
Hemiaster AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem. 3, p. 585.
Hemiaster DUNCAN and SLADEN, *1882*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, p. 78.
Hemiaster POMEL, *1883*, Classification méthodique et genera des échinides, p. 42.
Hemiaster, H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem. vol. 46, no. 2, p. 165.
Hemiaster JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 73.
Hemiaster LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc, 7, p. 498.
Hemiaster GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. Phys. Sci., vol. 2, p. 117.

Genotype, *Spatangus bufo* Al. Brongniart, 1822, from the Cenomanian of France, designated by Pomel (1883). This species has been figured by Agassiz and Desor (1847, pl. 6, fig. 7) and by d'Orbigny (1853, pl. 873).

HEMIASTER PARASTATUS (Morton)

Spatangus cor marinum? Parkinson. MORTON, *1830*, Am. Jour. Sci., ser. 1, vol. 18, p. 250, pl 3, fig. 10.
Spatangus parastatus MORTON, *1830*, idem, vol. 23, p. 294.
Spatangus parastatus MORTON, *1834*, Synopsis organic remains Cretaceous, p. 77, pl. 3, fig. 21.
Hemiaster parastatus DESOR in AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes (reprint), p. 141.
Holaster parastatus GABB, *1859*, Cat. invert. fossils Cretaceous, p. 19.
Hemiaster parastatus CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 92, pl. 48, figs. 1a–n.
Hemiaster (*Leymeriaster*) *parastatus* LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 501.

Occurrence.—NEW JERSEY: Gloucester County (type); Rancocas Creek, Vincentown (U. S. Nat. Mus. 29472, figured by Clark, F. B. Meek, collector); Timber Creek (fide Clark).

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia 1487.

HEMIASTER STELLA (Morton)

Spatangus stella MORTON, *1830*, Am. Jour. Sci., ser. 1, vol. 18, p. 245, pl. 3, fig. 11.
Spatangus parastatus (part) MORTON, *1834*, Synopsis organic remains Cretaceous, p. 78, pl. 3, fig. 18(?).
Hemiaster stella DESOR in AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes (reprint), p. 141.
Hemiaster stella CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 93, pl. 48, figs. 2a–d. Gives additional synonymy.
Hemiaster (*Integraster*) *stella* LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 504.

Occurrence.—NEW JERSEY: Timber Creek (type); near Blackwoodstown (U. S. Nat. Mus. 2208, figured by Clark, F. B. Meek, collector); Rancocas Creek, Vincentown, U. S. Nat. Mus. 29473, F. B. Meek, collector).

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia?

Genus AGASSIZIA Valenciennes, 1846

Agassizia VALENCIENNES, *1846*, Voyage sur *La Venus*, Zoophytes, pl. 1, figs. 2–2f.
Agassizia AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes (reprint), p. 126.
Agassizia DESOR, *1858*, Synopsis des échinides fossiles, p. 394.
Agassizia A. AGASSIZ. *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 88, 353.
Agassizia COTTEAU, *1875*, K. svenska vetenskakad. Handl., Bandet 13, no. 6, p. 82.
Agassizia POMEL, *1883*, Classification méthodique et genera des échinides, p. 35.
Agassizia H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 163.
Agassizia JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 70.
Agassizia LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 516.
Agassizia GRANT and HERTLEIN, *1938*. California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 113.

Genotype, *Agassizia scrobiculata* Valenciennes, 1846, by monotypy, living off the west coast of tropical and subtropical America (Clark). This species has been figured by A. Agassiz (1872, pl. 19a, figs. 1–3; pl. 19b, figs. 1–3) and by Grant and Hertlein (1938, pl. 29, figs. 2, 3; pl. 30, fig. 12; text fig. 10), who copy Valenciennes original figure. The anterior poriferous zones of the anterior paired petals are absent or obsolete. The genus is further characterized by having a peripetalous fasciole and a lateral fasciole. Its periproct is transverse.

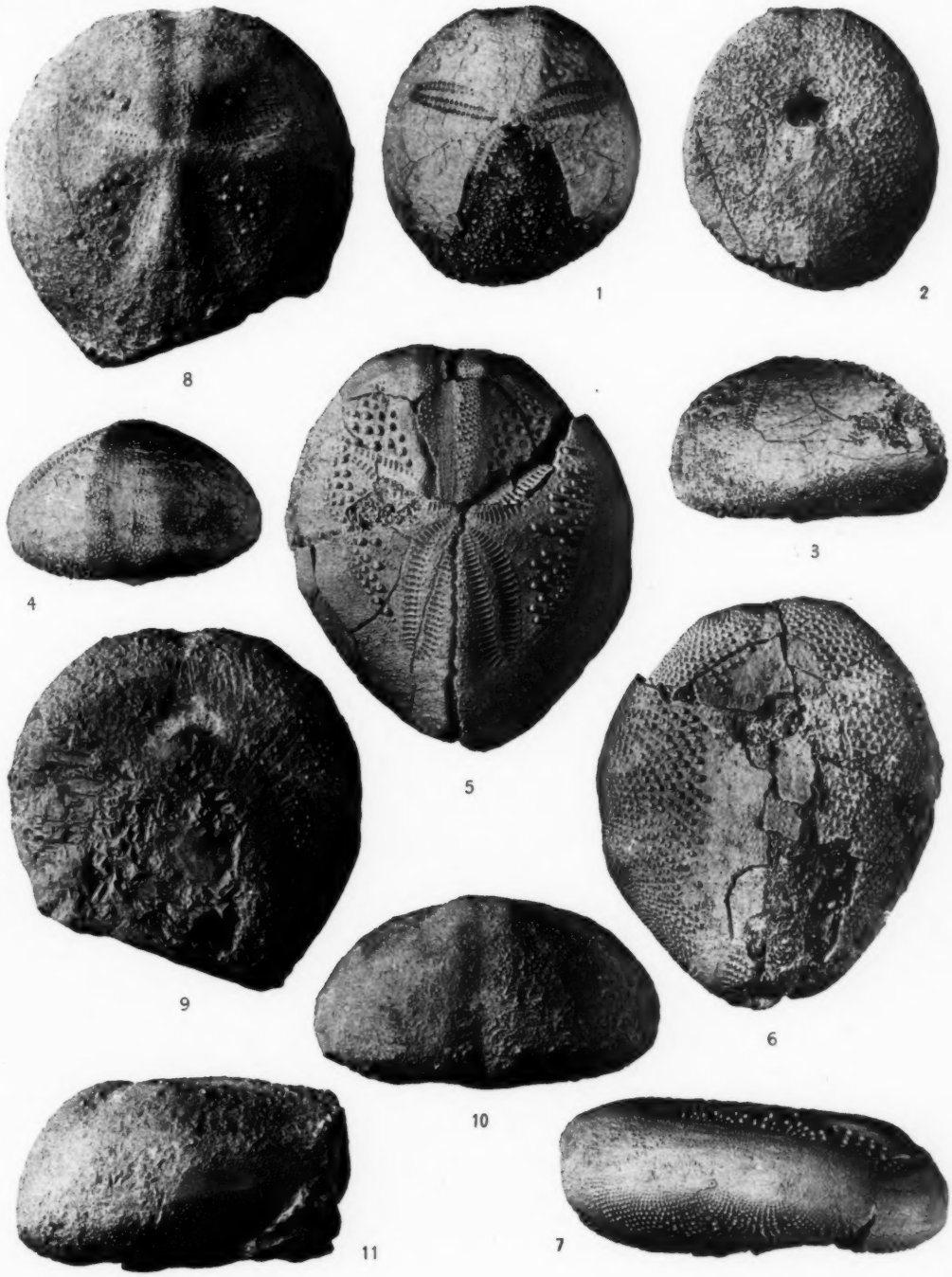
AGASSIZIA FLORIDANA de Loriol
Plate 3, figures 1–4

Agassizia floridiana DE LORIOL, *1887*, Recueil zool. suisse, ser. 1, t. 4, no. 3, p. 398, pl. 17, figs. 9–9f.
Agassizia conradi (Bouvé). CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 174, pl. 81, figs. 3a–d.
Agassizia inflata JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 70, pl. 12, figs. 2–4.
Agassizia egozcuei LAMBERT, *1922*, Annals and Mag. Nat. History, ser. 9, vol. 9, p. 596.
Agassizia inflata ARNOLD and CLARK, *1927*, Harvard College Mus. Comp. Zoology Mem., vol. 50, p. 56.
Agassizia conradi (Bouvé). PIJPERS, *1933*, Geog. geol. Mededeel. (Utrecht Rijksuniv. geog. en mineral.-geol. Inst.) Phys.-geol. Reeks no. 8, p. 92.
Agassizia caribbeana WEISBORD, *1934*, Bull. Am. Paleontology, vol. 20, no. 700, p. 74, pl. 8, figs. 1–6.

Occurrence.—FLORIDA: Near Gainesville (type, Prof. Wetherby, collector, fide de Loriol); about 12 miles north of Marianna (station 12058, Florida Basic Rock Co., W. C. Manfield and G. M. Ponton, collectors; station 14152, 1½ miles west of Springfield Church, W. C. Mansfield and C. W. Mumm, collectors); Ocala (station 7383, C. W. Cooke, collector); Zuber (station 6807, C. W. Cooke, collector); Newberry (station 6812, C. W. Cooke, collector); 2 miles northeast of Sumterville (station 12751, W. C. Mansfield and C. W. Mumm, collectors); 1¼ miles southwest of Inverness (station 7378, C. W. Cooke, collector); Steinhatchee River near Clara (station 14541, C. W. Cooke, collector; station 12747, W. C. Mansfield and G. M. Ponton, collectors); Crystal River Rock Co., 6 miles southeast of Crystal River (station 14141, W. C. Mansfield and C. W. Mumm, collectors);

EXPLANATION OF PLATE 7
All figures ×1

FIGS. *1–4*—*Eupatagus* (*Plagiobrissus*) *gardnerae* Cooke, n. sp. Holotype U. S. Nat. Mus. 498983, 6 miles west of Andalusia, Ala. Late Eocene. (p. 56)
5–7—*Eupatagus* (*Plagiobrissus*) *curvus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498984, Marianna. Fla. Late Eocene. (p. 56)
8–11—*Eupatagus* (*Brissopatagus*) *georgianus* Cooke, n. sp. Holotype, U. S. Nat. Mus. 498982, Albany, Ga. Late Eocene. (p. 58)



Cooke, Cenozoic Echinoids

1

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Cooke, Cenozoic Echinoids

Johnson's lime sink (U. S. Nat. Mus. 137881, L. C. Johnson, collector); between Inglis and Yankeetown, Levy County (station 14544, C. W. Cooke, collector); Archer, Sumter, and Williston (Florida Geol. Survey).

GEORGIA: Near Bainbridge (station 3770, U. S. Nat. Mus. 164744, figured by Clark and Twitchell, S. W. McCallie, collector); stations 6159, 6171, L. W. Stephenson, collector; station 7097, C. W. Cooke and W. C. Mansfield, collectors).

WEST INDIES: St. Bartholomew (types of *inflata* and *egozcuei*); Bonaire (*conradi*, fide Pijpers); Jamaica (*inflata*, fide Arnold and Clark); Cuba (type of *caribbeana*).

Geologic horizon.—Late Eocene, Ocala limestone and equivalents in the West Indies.

Figured specimens.—Station 1454, U. S. Nat. Mus. 499010, Steinhatchee River near Clara, Fla.; U. S. Nat. Mus. 325610, St. Bartholomew, figured by Jackson as type of *inflata;* U. S. Nat. Mus. 164744a, near Bainbridge, Ga., figured by Clark and Twitchell as *conradi* (Bouvé); Paleont. Research Inst., Camagüey Province, Cuba, figured by Weisbord as type and paratype of *caribbeana*.

Remarks.—This species was placed in the synonymy of *Hemiaster conradi* Bouvé (1851, p. 3, 2 text figs.) by Clark and Twitchell, but Bouvé's type, which is in the Museum of Comparative Zoology at Cambridge, Mass., is "absolutely unidentifiable even to the family, let alone genus or species," according to Prof. H. L. Clark, who kindly examined it for me. De Loriol's careful description and excellent figures leave no doubt that the specimen here figured represents the same species as his, though his type is not available.

Agassizia inflata Jackson, placed by Pijpers in the synonymy of *conradi* as identified by Clark and Twitchell, closely resembles *A. floridana* and probably is identical with it. It appears to differ in that its base is a little flatter, its peristome a little smaller, and its periproct a little lower; but these features, particularly the location of the periproct, are obscure in the type of *inflata*. Both *inflata* and *egozcuei* are based on part of *A. clevei* Cotteau (1875, p. 33, pl. 6, figs. 9, 10, not figs. 2–8), from which they differ in their more widely diverging anterior petals and in other features.

The largest individual in the collections of the National Museum is from Steinhatchee River, station 14541. It measures 36 by 34 by 28 mm.

AGASSIZIA RIMULATA (Ravenel)

Brissopsis rimulatus RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 4, figs. 3, 4.

Agassizia rimulata McCRADY in TUOMEY and HOLMES, *1857*, Pleiocene fossils of South Carolina, p. 5.

Brissopsis rimulatus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 154.

Occurrence.—SOUTH CAROLINA; Exact locality not recorded, possibly Santee Canal.

Geologic horizon.—Eocene (Ravenel).

Type.—Unknown; originally in the Ravenel collection at Charleston, S. C.

Remarks.—This species, which McCrady describes as conical, is known only from Ravenel's figure. It is probably not recognizable.

AGASSIZIA PORIFERA (Ravenel)

Brissopsis poriferus RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 4, figs. 5, 6.

Agassizia porifera McCRADY in TUOMEY and HOLMES, *1857*, Pleiocene fossils of South Carolina, p. 5, pl. 1, figs. 5–5b; pl. 2, figs. 4, 4a.

Agassizia porifera CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 212, pl. 97, figs. 1a–d.

Occurrence.—SOUTH CAROLINA: The Grove

EXPLANATION OF PLATE 8

All figures ×1

FIGS. *1–3—Echanthus georgiensis* (Twitchell). Holotype, U. S. Nat. Mus. 165683b, 5 miles south of Ellaville, Ga. Paleocene. (p. 37)

4—Cassidulus (*Cassidulus*) *sabistonensis* Kellum. Holotype. U. S. Nat. Mus. 353233, 2 miles north of Jacksonville, N. C. Early Miocene? (p. 31)

5, 6—Cassidulus (*Cassidulus*) *evergladensis* Mansfield. U. S. Nat. Mus. 499005, station 13377, Intracoastal Waterway canal 5 miles southwest of Little River, S. C. Two individuals. Pliocene. (p. 30)

7—Clypeaster oxybaphon Jackson. U. S. Nat. Mus. 499006, station 15067A, NW¼ sec. 36, T. 4 N., R. 13 W., Washington County, Fla. Late Oligocene. (p. 13)

Cooper River 5 miles northwest of Wando, Berkeley County (type); near Oakley Inlet.

Geologic horizon.—Pliocene, Waccamaw formation.

Type.—Unknown; originally in the Ravenel collection at Charleston, S. C.

Remarks.—There are no identified specimens of this species in the United States National Museum.

Subgenus ANISASTER Pomel, 1886

Anisaster POMEL, *1886*, Soc. géol. France Bull., sér. 3, t. 14, pp. 610, 612.
Anisaster COTTEAU, *1887*, Paléontologie française, Échinides éocènes, t. 1, p. 374.
Prenaster (*Anisaster*) LAMBERT and THIÉRY, *1925*, Nomenclature raisonnée des échinides, fasc. 8, p. 515.

Genotype, *Agassizia gibberula* Cotteau (1876), from the Eocene of Egypt, designated by Cotteau (1887, p. 381). This species has been figured by Cotteau and by de Loriol (1880, pl. 8, figs. 1–7).

Anisaster differs from typical *Agassizia* in that some of the pores of the anterior zones of its anterior paired ambulacra are not obsolete.

AGASSIZIA (ANISASTER) WILMINGTONICA Cooke, n. sp.
Plate 5, figures 9–13

Test ovoid, truncated behind: upper surface sloping gently from the apex to the posterior truncation, more steeply rounded at the front; rostrate behind; margin rounded; lower surface moderately inflated. Apical system back of the center; four genital pores separated by an elongated madreporite, which extends behind them. Anterior ambulacral area slightly depressed near the apex and peristome, flush at the margin; pores inconspicuous. Anterior paired petals slightly depressed; pore pairs of front zone small, diagonal distally, obsolete near the apex; pores of rear zone normal. Posterior petals about half as long as anterior pair; slightly depressed; interporiferous zones about as wide as poriferous zones; pores oval. Peristome transverse, cresent-shaped, labiate behind. Periproct transverse, oval, flush, terminal, at the top of the truncation. Hemipetalous fasciole curving downward to the marginal fasciole. Marginal fasciole curving downward to a V at the bottom of the truncation. Escutcheon ovate, extending from the peristome to the posterior end, reticulated with scales and tubercles. Remainder of surface covered with small tubercles, which are coarsest along the edges of the interambulacral areas.

Length, 21 mm.; width, 18.5 mm.; height, 14.2 mm.

Occurrence.—NORTH CAROLINA: City rock quarry near Wilmington (L. W. Stephenson, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—U. S. Nat. Mus. 499004.

Remarks.—The unique type of this species is less inflated than *A. floridana*, its front and back paired petals do not diverge at the same angle (the anterior pair are wider apart than the posterior), and the front posterior poriferous zones of the anterior pair are not obsolete distally. It was found in a bed slightly older than the zone occupied by *A. floridana*.

AGASSIZIA (ANISASTER) MOSSOMI Cooke, n. sp.
Plate 5, figures 14–17

Test nearly spherical, less tumid beneath, truncated behind. Apical system nearly central, with four genital pores, the posterior pair separated by an elongated madeporite, which extends behind them. Petals forming a nearly right angled X; more deeply sunken than customary for the genus; front pair half again as long as the back pair; pores of anterior zone of front pair small and oblique distally, very minute near the apex; interporiferous zones of back pair narrower than the poriferous zones. Anterior ambulacral area slightly sunken near the apex, flush at the margin. Peristome semilunate, with a posterior lip, located at the anterior third. Periproct large, transversely oval, terminal, at the top of the truncation. Marginal fasciole forming a V below the periproct, joined by the hemipetalous fasciole behind the anterior pair of petals. Interambulacral areas covered with close-set tubercles.

Length of holotype, 27 mm.; width, 24.5 mm.; height, 23.4 mm. Length of figured paratype, 25.2 mm.; width, 24 mm.; height, 22.3 mm.

Occurrence.—FLORIDA: Florida Rock Products quarry ¾ mile southwest of Brooksville (types, station 11113, C. W. Cooke and Stuart Mossom, collectors); Consolidated Rock Products quarry 3 miles northeast of Brooksville (station 12321, W. C. Mansfield and Herman Gunter, collectors). GEORGIA: Dawson-Albany road 3½ miles south of Sasser (station 4059, U. S. Nat. Mus. 165681, S. W. McCallie, collector, cast of interior); 1½ miles west of Muckalee Creek on road from Americus to Plains (station 12090, C. W. Cooke and W. H. Monroe, collectors, cast of interior). MISSISSIPPI: Rocky Branch, S.W. ¼ sec. 8, T. 8 N., R. 5 W., 1 mile north-northeast of Denham, Wayne County (station 14288a, W. C. Mansfield and F. S. MacNeil, collectors).

Geologic horizon.—Late Oligocene; Suwannee limestone (Florida), Flint River formation (Georgia), Chickasawhay marl (Mississippi).

Type.—U. S. Nat. Mus. 498989.

Remarks.—*Agassizia mossomi* is higher and more nearly spherical, its apex is farther forward, its petals are more deeply sunken, and the anterior pores of the front pair are more nearly complete than in *A. floridana* or *A. wilmingtonica*. The single distorted specimen from Mississippi (station 14288a) may represent a different species.

Family SPATANGIDAE Gray, 1825

Genus BRISSUS Gray, 1825

Brissus GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 431.
Brissus DESOR, *1858*, Synopsis des échinides fossiles, p. 403.
Brissus A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pt. 2, p. 356.
Brissus POMEL, *1883*, Classification méthodique et genera des échinides, p. 34.
Brissus H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 217.

Genotype, *Spatangus brissus* var. *unicolor* Leske, 1778, living in the tropical Atlantic, designated by H. L. Clark (1917, p. 217).

Brissus should not be credited to Leske because he did not accept it himself as of either generic or subgeneric rank but merely referred to it (1778, p. 245) as "Brissi Kleinii." His use of the word "Brissi" in the synoptic index (p. XX) was in the same sense. Nor can the use of *Brissus* on page 29 of his "Naturalis dispositio echinodermatum" be accepted, according to opinion 5 of the International Committee on Zoological Nomenclature.

BRISSUS UNICOLOR (Leske)

Spatangus brissus var. *unicolor* LESKE, *1778*, Naturalis dispositio echinodermatum, p. 248, pl. 26, figs. B, C.
Brissus unicolor GRAY, *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 431.
Brissus unicolor A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 97, 357, pl. 22, figs. 1, 2, pl. 37, fig. 19.
Brissus brissus H. L. CLARK, *1917*, idem, vol. 46, no. 2, p. 218.

Occurrence.—Southern Florida, tropical Atlantic, and Mediterranean Sea (Clark).

Geologic horizon.—Recent.

Remarks.—This species, as identified by Agassiz, has a peripetalous fasciole with reentrant angles, a subanal fasciole, widespreading anterior petals, which form almost a straight line and which are almost as long as the posterior petals.

BRISSUS? SPATIOSUS McCrady

Pericosmus spatiosus RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 4 (nomen nudum).
Brissus spatiosus McCRADY in TUOMEY and HOLMES, *1857*, Pleiocene fossils of South Carolina, p. 8, pl. 3, figs. 1–1c.
Meoma ventricosa (part) A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, p. 143.
Brissus spatiosus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 215.

Occurrence.—SOUTH CAROLINA: The Grove, Cooper River.

Geologic horizon.—Pliocene, Waccamaw formation; or late Miocene.

Remarks.—This species, known only from drawings of an imperfect cast, appears to be neither a *Brissus* nor a *Meoma*. It is probably unrecognizable. *Plagionotus ravenelianus* McCrady (1857, p. 10, pl. 3, figs. 3, 3a) and *Plagionotus holmesii* McCrady (1857, p. 9 pl. 3, figs. 2, 2a), described from fragments from the same formation, are unrecognizable. They may represent the same species.

Genus MEOMA Gray, 1851

Meoma GRAY, *1851*, Annals and Mag. Nat. History, ser. 2, vol. 7, p. 131.
Meoma DESOR, *1858*, Synopsis des échinides fossiles, p. 423.
Rhyssobrissus A. AGASSIZ, *1863*, Harvard College Mus. Comp. Zoology Bull., vol. 1, p. 27.
Hemibrissus POMEL, *1869*, Revue des échinodermes, p. 13. (Genotype, *Spatangus ventricosus* Lamarck.)
Brissus (*Meoma*) A. AGASSIZ, *1872*, Harvard Col-

lege Mus. Comp. Zoology Mem., vol. 3, pp. 142, 358.
Meoma POMEL, *1883*, Classification méthodique et genera des échinides, p. 35.
Meoma H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 220.
Meoma LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 495.
Meoma GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. Phys. Sci., vol. 2, p. 130.

Genotype, *Meoma grandis* Gray (1851, p. 132), living in the Gulf of California and along the Pacific coast of Mexico, by monotypy. Lambert and Thiéry identify this species as *Echinus grandis* Gmelin, but there is no evidence in Gray's paper that the correspondence in specific names is not accidental. Gray cites Australia as the habitat, but this is regarded by A. Agassiz and subsequent writers as probably an error.

MEOMA VENTRICOSA (Lamarck)

Spatangus ventricosus LAMARCK, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 29.
Meoma ventricosa LÜTKEN, *1864*, Naturh. Forening Kjöbenhavn, vidensk. Meddelelser, 1863, ser. 2, vol. 5, p. 120.
Brissus (*Meoma*) *ventricosa* A. AGASSIZ, *1872–1874*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 143, 358, 603, pl. 20, fig. 8; pl. 22, figs. 3, 4; pl. 26, figs. 31–34; pl. 38, figs. 24, 25.
Meoma ventricosa H. L. CLARK, *1917*, idem, vol. 46, no. 2, p. 221.
Meoma ventricosa H. L. CLARK, *1933*, New York Acad. Sci., Sci. Survey Porto Rico Virgin Islands, vol. 16, pt. 1, p. 92.

Occurrence.—Bahamas, southern Florida, Jamaica, and the Virgin Islands (Clark).

Geologic horizon.—Recent.

Remarks.—According to Clark this species attains a length of 188 mm., a width of 158 mm., and a height of 100 mm. A specimen in the collection of the Florida Geological Survey measures 156 mm. in length, 135 mm. in width, and 75 mm. in height.

Genus BRISSOPSIS Agassiz, 1840

Brissopsis AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, pp. 3, 16.
Brissopsis AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinides (reprint), p. 120.
Brissopsis WRIGHT, *1855*, Annals and Mag. Nat. History, ser. 2, vol. 15, p. 187.
Brissopsis DESOR, *1858*, Synopsis des échinides fossiles, p. 378.
Toxobrissus DESOR, *1858*, idem, p. 399.
Brissopsis A. AGASSIZ, *1872–74*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 95, 354, 593.
Brissopsis COTTEAU, *1875*, K. svenska vetensk. akad. Handl., Bandet 13, no. 6, p. 36.
Brissopsis POMEL, *1883*, Classification méthodique et genera des échinides, p. 34.
Toxobrissus POMEL, *1883*, idem, p. 34.
Brissopsis DUNCAN and SLADEN, *1884*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, p. 202.
Brissopsis COTTEAU, *1886*, Paléontologie française, Échinides éocènes, pp. 130, 182.
Brissopsis H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem. 46, no. 2, p. 199.
Brissopsis JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 81.
Brissopsis LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 489.
Brissopsis GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. in Math. and Phys. Sci., vol. 2, p. 126.

Genotype, *Brissopsis elegans* Agassiz, 1840, from the upper Eocene of France, by monotypy. This species has been described and figured by Cotteau (1886, p. 184, pls. 52, 53). The genotype of *Toxobrissus* is *Brissopsis crescenticus* Wright (1855, p. 187, pl. 6, figs. 2a–c), from Malta, having been designated by Pomel (1883, p. 34).

In regarding *Brissopsis* Agassiz, 1840, as a nomen nudum, H. L. Clark (1917, p. 199) seems to have overlooked the description on page 16, which must also be regarded as the description of *B. elegans*, cited on page 3 as the only species of the genus. Agassiz and Desor (1847, p. 121) list *B. elegans* as the first of seven fossil species and *Brissus lyrifer* Forbes as the first of three living species. They figure *B. lyrifer* (pl. 16, figs. 12, 12a), which is designated by Desor (1858, p. 378) as the type of *Brissopsis*.

As figured by Cotteau, the posterior petals of *Brissopsis elegans* are plainly separate throughout, and the inner poriferous zones are complete to the apical end—not atrophied near the apex as in *Brissopsis crescentica*, in which the apical parts of the posterior petals are nearly contiguous. Moreover, the madreporite is represented as attaining its maximum width between the posterior genital pores and not extending far behind them, whereas in *B. lyrifer* the madreporite is narrower between the genital pores and extends far behind them. These and other possible differences may be important enough to justify the revival of *Toxobrissus* as a

subgenus of *Brissopsis* if not its restoration to generic rank.

BRISSOPSIS ATLANTICA Mortensen

Brissopsis atlantica MORTENSEN, *1907*, Danish Ingolf-Expedition, pt. 2, Echinoidea, p. 160.
Brissopsis atlantica H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, pp. 200, 203.

Occurrence.—Southeastern coast of the United States.

Geologic horizon.—Recent.

Remarks.—This species, which I have not studied, was separated from *Brissopsis lyrifer* of authors. H. L. Clark regarded it as of somewhat doubtful validity.

BRISSOPSIS STEINHATCHEE Cooke, n. sp.
Plate 5, figures 29–32

Test cordate, half as high as wide; upper surface sloping gently forward from the posterior end; lower surface slightly convex; ambitus rounded. Apical system in front of the center; four genital pores, the front pair close together, the back pair separated by the attenuated end of the madreporite, which extends behind them. Anterior ambulacral area not petaloid, depressed throughout but nearly flush near the peristome; pores small, pore pairs divided by a granule. Anterior petals extending more than halfway to the ambitus, diverging at an angle of 130°, depressed, anterior poriferous zones nearly obsolete near the apex. Posterior petals somewhat longer, close together near the apex, diverging behind at an angle of about 40°, both sunken in a single depression; inner poriferous zones narrowing and becoming obsolete near the apex. Peristome curved, with rounded ends and a posterior lip. Periproct large, terminal, pear-shaped, about half as high as the test, near the top. Upper surface nearly smooth, probably granulated; lower surface covered with larger tubercles. Obscure traces of a peripetalous fasciole; subanal fasciole not apparent.

Length of holotype, 51 mm.; width, 42 mm.; height, about 21 mm. Another specimen is about 68 mm. long, 53 mm. wide, and about 25 mm. high.

Occurrence.—FLORIDA: Pit on Steinhatchee River north of U. S. Highway 19 near Clara, in Dixie County (station 14541, C. W. Cooke and W. D. Havens, collectors; station 12747, W. C. Mansfield and G. M. Ponton, collectors; station 14158, W. C. Mansfield and C. W. Mumm, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Station 14541, U. S. Nat. Mus. 498987.

Remarks.—The larger specimen measured is tentatively regarded as a senile variant. Its apical system appears to be much farther back, its anterior petals are curved forward, and its anterior ambulacral area is no more deeply sunken in spite of its larger size. It may represent an undescribed species.

BRISSOPSIS BLANPIEDI Grant and Hertlein
Plate 5, figures 23–28

Brissopsis blanpiedi GRANT and HERTLEIN, *1938*, Am. Midland Naturalist, vol. 19, no. 2, p. 482.

Test cordate, higher behind than in front. Upper surface inflated; lower surface slightly convex, arched posteriorly. Apical system slightly in front of the center; four close-set genital pores; madreporite between and behind the posterior pair of pores. Petals sunken, slightly curved outward; anterior pair diverging at an angle of 85°, extending about two-thirds the distance to the ambitus, a little longer than the posterior pair, which extend about halfway to the ambitus and diverge at an angle of 37°. Pores of paired petals large, oval, conjugate, those nearest the longitudinal axis obsolescent near the apical center; poriferous zones wider than the interporiferous zones. Anterior ambulacral area in a deep furrow, which deeply indents the margin but becomes obsolete near the peristome; pores small. Peristome large, oval, with a posterior lip; midway between the center and the anterior end. Periproct large, round, at the top of a truncation, which slopes steeply backward.

Length of largest topotype, 33 mm.; width, 25.5 mm.; height, 16 mm.

Occurrence.—MISSISSIPPI: Gully about 200 yards east of Highway 35 on Glaze farm ¼ mile west of Lemon and about 9 miles north of Raleigh, Smith County (station 13435, L. W. Stephenson and C. W. Cooke, collectors).

Geologic horizon.—Middle Oligocene, Byram formation.

Types.—California Acad. Sci. 7171–7173; figured topotype, U. S. Nat. Mus. 498998.

Remarks.—This species is known only from casts of the interior composed of bentonite and a few fragmentary molds. As the shell of *Brissopsis* is very thin, these casts show the shape very well.

Genus CYCLASTER Cotteau and Leymerie, 1856

Cyclaster COTTEAU and LEYMERIE, *1856*, Soc. géol. France Bull., sér. 2, t. 13, p. 345.
Cyclaster POMEL, *1883*, Classification méthodique et genera des échinides, p. 34.
Cyclaster COTTEAU, *1886, 1887*, Paléontologie française, Échinides éocènes, t 1, pp. 133, 442.
Cyclaster LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 485.

Genotype, *Cyclaster declivus* Cotteau, 1856, from the upper Eocene of France, by monotypy. This species is figured by Cotteau (1887, p. 444, pl. 121, fig. 4; pl. 122). *Cyclaster* was regarded by Desor (1858, p. 378) as a synonym of *Brissopsis*, from which it differs in having three genital pores instead of four, an incomplete instead of a complete peripetalous fasciole, in the shape of its petals, and in other features.

CYCLASTER DREWRYENSIS Cooke, n. sp.
Plate 9, figures 9–11

Test cordate, truncated behind. Upper surface inflated; arched and rostrate between the apex and the periproct. Lower surface slightly swollen. Margin rounded. Apical system slightly in front of the center; three genital pores; madreporite confined to the right quadrant. Petals short, broad, straight, open at the ends, nearly equally long; anterior pair diverging at an angle of approximately 130°, posterior at approximately 60°; interporiferous zones nearly as wide as poriferous zones; pores oval, conjugate. Anterior ambulacral area not petaloid, slightly furrowed, deepest near the apex and peristome but broad and shallow at the ambitus; pores small, pairs oblique, pores of a pair separated by a granule. Peristome small, oval, with a posterior lip, located near the front. Periproct small, broadly oval, longitudinal, at the top of the truncated posterior end. Surface granulated. Tubercles small and scattered on upper surface, set in scrobiculae on lower surface. Partial peripetalous fasciole nearly straight between the ends of the posterior petals, deeply incurved between the lateral petals, and vanishing in front of the anterior paired petals. Subanal fasciole short, wide, elliptical.

Length, 41 mm.; width, 36 mm. (originally wider); height, 26 mm.

Occurrence.—ALABAMA: Lowest bed at Drewry, Monroe County, in sec. 15, T. 6 N., R. 8 E. (holotype, station 10026, C. W. Cooke, collector); 2 or 3 miles southeast of Whatley, Clarke County (paratype, station 2957, Frank Burns, collector); St. Stephens Bluff, Washington County, bed 3 of section (station 6712, C. W. Cooke, collector; Florida Geol. Survey I-1386).

Geologic horizon.—Early Oligocene, limestone facies of the Red Bluff.

Types.—Holotype, U. S. Nat. Mus. 372880; paratype, U. S. Nat. Mus. 154148.

Remarks.—The specimen from St. Stephens Bluff is merely a partly corroded fragment, but there appears to be little doubt of its identity.

Genus MACROPNEUSTES Agassiz, 1847

Macropneustes AGASSIZ in AGASSIZ and DESOR, *1847*, Annales sci. nat. (zoologie), ser. 3, vol. 8, p. 9. (Reprint, p. 114.)
Macropneustes DESOR, *1858*, Synopsis des échinides fossiles, p. 409.
?Schizobrissus POMEL, *1869*, Revue des échinodermes, p. 13.
Peripneustes COTTEAU, *1875*, K. svenska ventens.-akad. Handl., Bandet 13, no. 6, p. 38.
Macropneustes POMEL, *1883*, Classification méthodique et genera des échinides, p. 32.
?Schizobrissus POMEL, *1883*, idem, p. 35.
?Macropneustes DUNCAN and SLADEN, *1884*, Palaeontologia Indica, ser. 14, vol. 1, pt. 3, p. 229.
?Mauritanaster LAMBERT, *1920*, Soc. acad. de l'Aube Mem., t. 84, p. 22.
Macropneustes JACKSON, *1922*, Carnegie Inst. Washington Pub. 306, p. 84.
Macropneustes LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 493.
Macropneustes GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 127.

Genotype, *Micraster deshayesii* Agassiz, designated by Jackson (1922, p. 84), from the Eocene of the Paris Basin. This species has been figured by Desor (1858, pl. 44, figs. 2, 3) and by Cotteau (1886, p. 141, pls. 31–33). It has a nearly circular peripetalous fasciole and a bilobed subanal fasciole.

There seems to be a good deal of variation

in the shape and location of the fascioles in *Macropneustes*, and in some individuals one or both of the fascioles may be incomplete or missing. *Mauritanaster*, whose chief difference from *Macropneustes* is the apparent lack of fascioles, probably is a synonym.

MACROPNEUSTES MORTONI (Conrad)

Holaster mortoni CONRAD, *1850*. Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 2, p. 40, pl. 1, fig. 10.
Macropneustes cubensis COTTEAU, *1875*, K. svenska vetensk.-akad. Handl., vol. 13, no. 6, p. 6.
Macropneustes cubensis COTTEAU, *1876*, Soc. géol. France Bull., ser. 3, t. 5, p. 130.
Macropneustes cubensis COTTEAU, *1881*, Soc. géol. Belgique Annales, t. 9, p. 48, pl. 4, fig. 7.
Macropneustes cubensis EGOZCUE, *1897*, Com. mapa geol. España Bol., vol. 22, p. 91, pl. 23, figs. 1–4; pl. 25, fig. 7.
Macropneustes mortoni CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 155, pl. 72, figs. 1a–d.
Mauritanaster cubensis LAMBERT, *1923*, Soc. cubana historia nat. "Felipe Poey" Mem., vol. 5, no. 1, p. 44. (*1924*, Reprint, p. 42.)
Antillaster castroi LAMBERT, *1923*, idem, p. 44. (*1924*, Reprint, p. 42.)
Trachypatagus castroi LAMBERT, *1923*, idem, p. 48. (*1924*, Reprint, p. 46.)
Antillaster castroi SANCHEZ ROIG, *1923*, idem, 35. (*1924*, Reprint, p. 33.)
Mauritanaster cubensis SANCHEZ ROIG, *1923*, idem, p. 38. (*1924*, Reprint, p. 36.)
Macropneustes mortoni COOKE, *1926*, Alabama Geol. Survey Special Rept. 14, pl. 96, figs. 1a–b.

Occurrence.—GEORGIA: Palmyra, Lee County (type); power plant on Kinchafoonee Creek north of Albany (station 7121, C. W. Cooke and J. E. Brantly, collectors; station 10507, C. W. Cooke and T. M. Prettyman, collectors); just above bridge of Albany Northern Railway over Muckafoonee Creek near Albany (station 3617, T. W. Vaughan, collector); east side Flint River at power plant above Albany (station 12021, C. W. Cooke and W. H. Monroe, collectors); east bank Flint River at mouth of creek in the northeastern corner of Dougherty County (station 7235, C. W. Cooke, collector).

ALABAMA: Claiborne road west of Double Branches, 2½ miles west of Monroeville (station 6730, C. W. Cooke, collector); creek at road in SW. ¼ sec. 7, T. 6. N., R. 6 E., 1½ miles southwest of Perdue Hill, Monroe County (station 10043, C. W. Cooke and Julia Gardner, collectors); near middle of E. ½ sec. 34, T. 8 N., R. 3 E., 5 miles southeast of Whatley, Clarke County, bed 2 of section (station 7159, C. W. Cooke, collector, figured by Cooke, 1926); Fail Post Office, Choctaw County (station 2864, Charles Schuchert, collector, figured by Clark and Twitchell, 1915); Little Stave Creek, secs. 20, 21, T. 7 N., R. 2 E., Clarke County (Alabama Geol. Survey, Winnie McGlamery, collector); St. Stephens Bluff, Tombigbee River (Alabama Geol. Survey); Frankville, Washington County (Alabama Geol. Survey).

FLORIDA: State park near Marianna (Florida Geol. Survey I-3957, Herman Gunter and Clarence Simpson, collectors).

CUBA: San Martin, Matanzas (type of *M. cubensis*); Finca Cervantes, San Jose de las Lajas, Habana (Mario Sanchez Roig, collector).

Geologic horizon.—Late Eocene; Ocala limestone (Georgia, Florida, and central Alabama). Jackson group (western Alabama).

Type.—Probably Acad. Nat. Sci. Philadelphia.

Figured specimens.—Clark and Twitchell, 1915, U. S. Nat. Mus. 146468; Cooke, 1926, U. S. Nat. Mus.

Remarks.—*Macropneustes mortoni* has a fasciole that crosses the ends of the petals and which is somewhat reentrant between the lateral paired petals. It has also a bilobed subanal fasciole. The petals are normally flush but may become sunken. Specimens from Cuba identified by Dr. Sanchez Roig as *Antillaster castroi* and *Mauritanaster cubensis* have somewhat sunken petals. These specimens are too badly corroded to show fascioles, but even well-preserved Cuban specimens are said to lack them. Nevertheless there seems little doubt that these corroded specimens are congeneric with *Macropneustes mortoni*, even though one might question their specific identity.

MACROPNEUSTES CAROLINENSIS Clark

Macropneustes carolinensis CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 154, pl. 71, figs. 5a–d.
Mauritanaster carolinensis LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 493.

Occurrence.—NORTH CAROLINA: Wilmington (type, station 3602, Frank Burns, collector); J. A. Stokes farm 2 miles north of creek near Maple Cypress, Craven County (station 8165, J. A. Cushman collector); Southern Drainage Canal about 9 miles northwest of Vanceboro, Pitt County (station 11810, W. C. Mansfield, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—U. S. Nat. Mus. 164651.

Remarks.—A well-preserved specimen of

this species shows distinctly a marginal fasciole, which passes above the periproct, but no subanal fasciole. The lack of a subanal fasciole throws doubt on the reference of this species to *Macropneustes*, but the presence of a marginal fasciole apparently removes it from *Mauritanaster* if that genus is valid.

Genus HOLASTER Agassiz, 1836

Holaster AGASSIZ, *1836*, Soc. sci. nat. Neuchatel, t. 1, p. 183.
Holaster AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, p. 1.
Holaster AGASSIZ and DESOR, *1847*, Catalogue raisonné des échinodermes, p. 132.
Holaster D'ORBIGNY, *1853*, Paléontologie française, Terrain crétacé, t. 6, p. 71.
Holaster DESOR, *1858*, Synopsis des échinides fossiles, p. 336.
Holaster POMEL, *1883*, Classification méthodique et genera des échinides, p. 45.
Holaster LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 401.

Genotype, *Spatangus nodulosus* Goldfuss, 1829, from the Cenomanian of Europe, designated by Lambert and Thiéry, 1924. This species was figured by d'Orbigny (1853, p. 104, pl. 818) under the name *Holaster carinatus* (Lamarck), which name is not valid (International Rules, Art. 31) because Lamarck misidentified the species (*Ananchytes carinata*) with *Spatangites carinatus* Leske. (D'Orbigny, 1853, p. 106.)

HOLASTER CINCTUS (Morton)

Ananchytes cinctus MORTON, *1830*, Acad. Nat. Sci. Philadelphia Jour., ser. 1, vol. 6, p. 200.
Ananchytes fimbriatus MORTON, *1830*, idem, p. 200.
Ananchytes cinctus MORTON, *1830*, Am. Jour. Sci., ser. 1, vol. 18, p. 246, pl. 3, fig. 7.
Ananchytes fimbriatus MORTON, *1830*, idem, p. 245, pl. 3, fig. 9.
Ananchytes cinctus MORTON, *1834*, Synopsis Organic Remains Cretaceous, p. 78, pl. 3, fig. 19.
Anancytes fimbriatus MORTON, *1834*, idem, p. 78, pl. 3, fig. 20.
Holaster cinctus AGASSIZ, *1840*, Catalogus systematicus ectyporum echinodermatum, p. 1.
Cardiaster cinctus BRONN, *1853–56*, Lethaea geognostica, vol. 2, pt. 5, p. 205.
Cardiaster cinctus CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 83, pl. 36, figs. 2a–h. Contains additional synonymy.

Occurrence.—NEW JERSEY: Rancocas Creek, Vincentown (U. S. Nat. Mus. 29467, F. B. Meek, collector).

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia, (Figured by Clark.)

Remarks.—This species is represented in the United States National Museum by three imperfect individuals, which show the sculpture clearly. Lack of a fasciole removes it from *Cardiaster*. The anterior and posterior pairs of genital pores are widely separated. The decoration may be coarser, and the anterior sulcus is much deeper than in *Holaster nodulosus*, but in generic features the species seems to agree with typical *Holaster*.

Genus HEMIPATAGUS Desor, 1858

Hemipatagus DESOR, *1858*, Synopsis des échinides fossiles, p. 416.
Hemipatagus POMEL, *1883*, Classification méthodique et genera des échinides, p. 29.
Maretia Gray. COTTEAU, *1885*, Paléontologie française, Échinides éocènes, t. 1, p. 24.
Chuniola GAGEL, *1903*, K. preuss. geol. Landesanstalt Jahrb. 1902, Band 23, Heft 3, p. 531.
Hemipatagus LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 456.

Genotype, *Spatangus hoffmanni* Goldfuss, from the Tertiary of Germany, by original designation. *Hemipatagus* differs from *Eupatagus* in the elongation of its periproct, which is transverse, not longitudinal. It apparently lacks a peripetalous fasciole but has a subanal fasciole. Desor's (1858, pl. 44, fig. 5) figure of the genotype shows a subanal fasciole, though his description of the genus specifies "point de fascioles." The shape of *Hemipatagus* is strongly cordate—a feature that distinguishes it from most species of *Eupatagus*, though species of *Eupatagus* (*Brissopatagus*) are somewhat cordate.

HEMIPATAGUS ARGUTUS Clark

Hemipatagus argutus CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 150, pl. 69, figs. 1a–d.

Occurrence.—MISSISSIPPI: Chickasawhay River at Enterprise (type, station 2629, Frank Burns, collector); Rose Hill road 8 miles west of Enterprise (station 2621, Frank Burns, collector); north of mile post 20, New Orleans & Northeastern Railway, 1 mile north of Wautubbee, Clarke County (station 6479, E. N. Lowe and C. W. Cooke, collectors).

Geologic horizon.—Middle Eocene, Lisbon formation.

Type.—U. S. Nat. Mus. 141107.

HEMIPATAGUS SUBROSTRATUS Clark

Hemipatagus subrostratus CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 151, pl. 69, figs. 2a–b.

Occurrence.—NORTH CAROLINA: Wilmington (type, station 3602, Frank Burns, collector; city rock quarry, U. S. Nat. Mus. 166516, L. W. Stephenson, collector).

Geologic horizon.—Late Eocene, Castle Hayne marl.

Type.—U. S. Nat. Mus. 164652.

Remarks.—This species is represented in the United States National Museum by three individuals, all imperfect. The one numbered 166516 retains part of a subanal fasciole, but there is no peripetalous fasciole.

Genus EUPATAGUS Agassiz, 1847

Eupatagus AGASSIZ in AGASSIZ and DESOR, *1847*, Ann. Sci. nat., ser. 3, t. 8, p. 9 (reprint, p. 115).
Eupatagus DESOR, *1858*, Synopsis des échinides fossiles, p. 413.
Spatangus (*Eupatagus*) A. AGASSIZ, *1872*, *1873*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 128, 572.
Eupatagus POMEL, *1883*, Classification méthodique et genera des échinides, p. 28.
Euspatangus COTTEAU, *1885*, Paléontologie française, Échinides éocènes, t. 1, p. 44.
Eupatagus H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 226.
Brissoides (*Brissoides*) LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 450.
Eupatagus JACKSON, *1922*. Carnegie Inst. Washington Pub. 306, p. 88.
Eupatagus GRANT and HERTLEIN, *1938*, Univ. California (Los Angeles) Pub. in Math. and Phys. Sci., vol. 2, p. 134.

Genotype, *Eupatagus valenciennesii* Agassiz, living around Bass Strait, Australia (Clark), designated by Pomel (1883). This species is figured by A. Agassiz (1873, pl. 15a, figs. 3, 4). It has broad, rounded, nearly closed, flush paired petals, with narrow poriferous zones. Its peripetalous fasciole is without indentations. Its subanal fasciole is described as closed, heart-shaped, broad, and with an indistinct anal branch. A few large tubercles lie within the peripetalous fasciole in the four lateral interambulacral areas. Its anterior ambulacral area is not petaloid nor depressed.

Students of fossil echinoids interpret *Eupatagus* much more broadly than either Alexander Agassiz or H. L. Clark, who restrict the genus to the genotype. In the present paper *Gymnopatagus*, *Plagiobrissus*, and *Brissopatagus* are interpreted as subgenera of *Eupatagus*, with which they agree in the structure of such vital parts as are revealed by the test alone.

KEY TO THE EARLY TERTIARY SPECIES OF EUPATAGUS OF THE EASTERN UNITED STATES

1. Region in front of the apical system lower than that behind it.
  2. Interporiferous zones much wider than poriferous zones; upper surface rugose; spines in lines ..... *mooreanus.*
  2. Interporiferous zones not wider than poriferous zones.
    3. Highest point at posterior end ..... *dixie.*
    3. Highest point at apical system ..... *gardnerae.*
1. Region in front of the apical system not lower than that behind it.
  2. Anterior ambulacral area flattened, not conspicuously furrowed.
    3. Petals straight; no large tubercles in anterior interambulacral areas ..... *carolinensis.*
    3. Petals not straight; large tubercles in anterior interambulacral areas.
      4. Posterior petals curved backward ..... *curvus.*
      4. Posterior petals curved forward ..... *ocalanus.*
  2. Anterior ambulacral areas furrowed; petals in broad depressions; anterior end humpbacked.
    3. Apical system far forward.
      4. Interporiferous zones wider than poriferous zones ..... *georgianus.*
      4. Interporiferous zones not wider than poriferous zones ..... *alabamensis.*
    3. Apical system not far forward (Paleocene) ..... *primus.*

Subgenus GYMNOPATAGUS Döderlein, 1901

Gymnopatagus DÖDERLEIN, *1901*, Zool. Anzeiger, vol. 24, p. 22.
Gymnopatagus H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, p. 226.
Gymnopatagus LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 453.

Genotype, *Gymnopatagus valdiviae* Döderlein (1901, p. 23), living off the coast of East Africa, by monotypy. This species is described as having a very thin heart-shaped test, with the forward ambulacrum sunken in a rather broad and deep furrow; lateral ambulacra petaloid, small, closed;

subanal and peripetalous fascioles present; a few very large primary spines confined within the peripetalous fasciole. As I have not seen this species, I am basing my interpretation of *Gymnopatagus* on H. L. Clark's (1917, pl. 159, figs. 2–6) figures of *Gymnopatagus pulchellus* A. Agassiz and Clark, which apparently differs considerably from *G. valdiviae*. The linear arrangement of its tubercles suggest *Maretia* Gray, 1855 (genotype *Spatangus planulatus* Lamarck = *Spatangus ovatus* Leske), which, however, is said to lack a peripetalous fasciole.

Eupatagus (Gymnopatagus) mooreanus Pilsbry
Plate 1, figure 16

Eupatagus mooreanus Pilsbry, *1914*, Acad. Nat. Sci. Philadelphia Proc., vol. 66, p. 206, pl. 8.
Eupatagus floridanus (part) Clark, *1915*, U. S. Geol. Survey Mon. 54, p. 176, pl. 83, figs. 1a–2b (not pl. 82, figs. 2a–d).
Maretia twitchelli Lambert in Sanchez Roig, *1926*, Bol. minas (Cuba), vol. 10, p. 112.
Maretia clarki Lambert in Sanchez Roig, *1926*, idem, p. 112.

Occurrence.—Florida: Withlacoochee River (type, C. M. Moore, collector); Levy County between Inglis and Yankeetown (station 14544, C. W. Cooke and W. D. Havens, collectors); Inglis (station 11118, Herman Gunter and Stuart Mossom, collectors); phosphate pit 1¼ miles southwest of Inverness (station 7378, C. W. Cooke, collector); 5 miles southwest of Inverness (station 7382, C. W. Cooke, collector); phosphate mine north of Dunnellon (station 7381, C. W. Cooke, collector); Silver Springs, Marion County (station 14572, Mr. Ray, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—Acad. Nat. Sci. Philadelphia, 1147.

Remarks.—This striking robust species has a spread-wings-shaped escutcheon enclosed in the subanal fasciole and perforated by at least seven ambulacral pores on each side. An arrowhead-shaped plastron with tubercles on each side adjoins it anteriorly and extends halfway to the peristome. The ambulacral areas on the base are thick and smooth, like a deposit of callus. A peripetalous fasciole without indentations can be detected on well-preserved individuals.

Two of the three individuals on which *Eupatagus floridanus* Clark was based are conspecific with *Eupatagus mooreanus* Pilsbry, which was described while Clark and Twitchell's monograph was in course of publication. In 1926 Lambert chose them as types of his *Maretia clarki* and *Maretia twitchelli*, which therefore fall into the synonymy of *E. mooreanus*. Both specimens are from Florida, but the exact locality is unknown.

Subgenus Plagiobrissus Pomel, 1883

Brissus (*Plagionotus*) Agassiz in Agassiz and Desor, *1847*, Catalogue raisonné des échinodermes (reprint), p. 119, not *Plagionotus* Mulsant, 1842.
Plagiostomus d'Orbigny, *1853*, Paléontologie française, Terrain crétacé, t. 6, p. 151, not *Plagiostomus* Sowerby, 1812.
Plagiobrissus Pomel, *1883*, Classification méthodique et genera des échinides, p. 29.
Plagiobrissus H. L. Clark, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 207.
Plagiobrissus Lambert and Thiéry, *1924*, Nomenclature raisonné des échinides, fasc. 7, p. 495.
Plagiobrissus Jackson, *1922*, Carnegie Inst. Washington Pub. 306, p. 83.

Genotype, *Spatangus pectoralis* Lamarck, 1816, = *Echinus grandis* Gmelin, 1788, living off Florida, Bahamas, and Brazil.

Eupatagus (Plagiobrissus) grandis (Gmelin)

Echinus grandis Gmelin, *1791*, Linné, Systema naturae, t. 1, pt. 6, p. 3200.
Spatangus pectoralis Lamarck, *1816*, Histoire naturelle des animaux sans vertèbres, t. 3, p. 29.
Brissus pectoralis Agassiz, *1836*, Soc. sci. nat. Neuchatel Mém., t. 1, p. 185.
Plagionotus pectoralis Agassiz and Desor, *1847*, Catalogue raisonné des échinodermes (reprint), p. 119, pl. 16, fig. 15.
Metalia pectoralis A. Agassiz, *1872*, *1874*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 144, 361, 600, pl. 21, figs. 4, 5.
Plagiobrissus pectoralis Pomel, *1883*, Classification méthodique et genera des échinides, p. 30.
Plagiobrissus grandis H. L. Clark, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 46, no. 2, p. 207, pl. 146, figs. 21, 22.
Plagiobrissus grandis H. L. Clark, *1933*, New York Acad. Sci., Sci. Survey Porto Rico Virgin Islands, vol. 16, pt. 1, p. 90.
Occurrence.—Off Tampa, Fla., Nassau, Bahamas, and Bahia, Brazil (Clark).

Geologic horizon.—Recent.

Eupatagus (Plagiobrissus) holmesii (McCrady)

Plagionotus holmesii McCrady in Tuomey and Holmes, *1857*, Pleiocene fossils of South Carolina, p. 9, pl. 3, figs. 2, 2a.

Plagionotus ravenelianus McCRADY, *1857*, idem, p. 10, pl. 3, figs. 3, 3a.
Plagiobrissus holmesi STEFANINI, *1911*, Soc. geol. italiana Boll., vol. 30, p. 707.
Plagiobrissus ravenelianus STEFANINI, *1911*, idem, p. 707.
Metalia raveneliana CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 215.
Metalia holmesi CLARK and TWITCHELL, *1915*, idem, p. 215.

Occurrence.—SOUTH CAROLINA: Smith's, Goose Creek (Yeamans Hall); The Grove, Cooper River.

Geologic horizon.—Pliocene, Waccamaw formation.

Remarks.—These two nominal species of McCrady, which were based on fragments, were placed in the synonymy of *Metalia pectoralis* (=*Plagiobrissus grandis*) by A. Agassiz (1872, p. 145), though later (1874, p. 751) he appears to have regarded them as two valid species. Judgment as to their true relationships had better be reserved until better representatives of them have been obtained.

EUPATAGUS (PLAGIOBRISSUS) DIXIE
Cooke, n. sp.
Plate 6, figures 1–3

?Eupatagus floridanus (part) CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 176, pl. 82, figs. 2a–d (not pl. 83, figs. 1a–c, 2a–d).
?Brissoides (*Koilospatangus*) *floridanus* LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 454.

Test oval, depressed, truncate behind, margin rounded, upper surface little more inflated than the lower, rostrate above the periproct. Apical system in front of the center; four genital pores close together, the posterior pair separated by the elongated madreporite. Anterior ambulacral area not at all petaloid nor depressed. Petals somewhat sunken; anterior pair curved slightly forward, diverging at an angle of about 145°, extending about three-fourths of the way to the margin, shorter than the posterior pair; posterior petals straight, diverging at an angle of nearly 50°, extending nearly two-thirds of the way to the margin; poriferous zones wider than interporiferous zones; pores conjugate. Peristome large, wider than long, evenly curved in front, labiate behind. Periproct about as large as the peristome, pear-shaped, above the margin, on the steeply truncated end. Peripetalous fasciole without marked indentations. Subanal fasciole, heart-shaped, enclosing a spread-wings-shaped escutcheon covered with large tubercles; remainder of lower posterior interambulacral area covered by closer, smaller tubercles. Ambulacral areas on lower surface bare. Paired interambulacral areas on lower surface covered by lines of large tubercles. Upper surface well covered by small tubercles; large tubercles confined within the peripetalous fasciole, most abundant between and adjacent to the paired petals.

Length, 47 mm.; width, 38 mm.; height, 20 mm. One specimen (fig. 1) measures 70 mm. in length.

Occurrence.—FLORIDA: Taylor County rock pit 1 mile north of Mayo, Lafayette County (type, G. M. Ponton, collector); 5.2 miles west of Mayo (station 14537, C. W. Cooke, collector); Dixie County north of U. S. 19 east of Steinhatchee River, opposite Clara (station 14541, figured paratype, C. W. Cooke and W. D. Havens, collectors). Casts of the interior, probably this species: Alachua (station 6791, T. W. Vaughan and C. W. Cooke, collectors); Arredonda (station 380, L. C. Johnson, collector); Johnson's lime sink, Levy County (type of *Eupatagus floridanus* Clark as restricted by Lambert, station 365, L. C. Johnson, collector).

GEORGIA: Dam on Flint River at Kinchafoonee Creek north of Albany (station 7121, C. W. Cooke, collector; station 10507, C. W. Cooke and T. M. Prettyman, collectors).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 498985; figured paratype, 498986, station 14541.

Remarks.—*Eupatagus dixie* has narrower interporiferous zones than either *E. carolinensis* or *E. ocalanus*, its anterior ambulacral area is not at all depressed, its anterior paired petals are not so widely diverging, and the arrangement and distribution of its tubercles are different.

W. B. Clark figured as *Eupatagus floridanus* three individuals from different places and in different museums. Two of these represent *Eupatagus* (*Gymnopatagus*) *mooreanus* Pilsbry, which was described while Clark and Twitchell's monograph was in course of publication. Clark's description was based on these two specimens, which are well preserved. The third figured specimen, an internal cast, shows few specific characters, and the exact location from which it came is unknown. This cast was chosen as the type of *E. floridanus* by Lam-

bert (in Sanchez Roig, 1926, p. 112). Though this cast agrees in recognizable characters with *Eupatagus dixie*, there must always remain some doubt as to its true identity. To apply the name *E. floridanus* to this species would inevitably result in confusion.

EUPATAGUS (PLAGIOBRISSUS) GARDNERAE Cooke, n. sp.

Plate 7, figures 1–4

Test oval, upper surface inflated, lower surface gently rounded, margin rounded; anterior ambulacral area flattened but not depressed. Apical system anteriorly eccentric; four genital pores close together. Petals flush, nearly the same length; anterior pair widely diverging; interporiferous zones of anterior pair narrow, very narrow at the ends; pores round, equal except at the inner end of the anterior zones of the anterior petals, where they are much smaller; 25 pairs in each zone. Pores of anterior ambulacral area very small; pore pairs oblique. Peristome large, oval, labiate, somewhat farther forward than the apical center. Traces of a peripetalous fasciole can be detected, but the unbroken part of the posterior end is so deeply corroded that the subanal fasciole is obliterated. At least a dozen large perforated tubercles within the peripetalous fasciole in the anterior interambulacral areas; tubercles in the other interambulacral areas obliterated.

Length, 40 mm.; width, 37.4 mm.; height, 24.3 mm.

Occurrence.—ALABAMA: Stream 6 miles west of Andalusia, on line between secs. 20 and 29, T. 4 N., R. 15 E. (station 10014, C. W. Cooke and Julia Gardner, collectors).

Geologic horizon.—Late Eocene, Ocala limestone, just above *Periarchus lyelli* bed at base of formation.

Type.—U. S. Nat. Mus. 498983.

Remarks.—This species, based on one imperfect specimen, appears to be more closely related to *Eupatagus* (*Plagionotus*) *ocalanus* than to any other species. *E. gardnerae* is proportionately shorter, higher, and more evenly tumid than *ocalanus;* its petals are flush, and the tubercles in the anterior interambulacral areas are larger.

EUPATAGUS (PLAGIOBRISSUS) CAROLINENSIS Clark

Eupatagus carolinensis CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 153, pl. 71, figs. 3a–d, 4.
Brissoides carolinensis LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, p. 450.

Occurrence.—NORTH CAROLINA: Wilmington (type, L. W. Stephenson, collector; figured specimen, Frank Burns, collector; station 10340, C. W. Cooke, collector); Northeast Cape Fear River 3¼ miles above Castle Hayne (U. S. Nat. Mus. 164495, L. W. Stephenson, collector).
ALABAMA: Rock House Bluff, Conecuh River, sec. 28 or 29, T. 3 N., R. 14 E., Conecuh County (station 6750, C. W. Cooke, collector, identification doubtful).

Geologic horizon.—Late Eocene; Castle Hayne marl (North Carolina), Ocala limestone (Alabama).

Type.—U. S. Nat. Mus. 166484.

Remarks.—This species has a peripetalous fasciole without conspicuous indentations and a heart-shaped subanal fasciole, from which apparently arise a short, incomplete fasciole on each side of the periproct, though these lateral fascioles are very obscure.

EUPATAGUS (PLAGIOBRISSUS) CURVUS Cooke, n. sp.

Plate 7, figures 5–7

Test ovate, low, margin rounded. Anterior ambulacral area not at all petaloid, slightly depressed. Anterior pair of petals nearly as long as the posterior pair, widely diverging, extending more than two-thirds the way to the margin, constricted near the tips; interporiferous zones as wide as poriferous zones at the tips, twice as wide elsewhere; poriferous zones convex near the apex, straighter near the tip. Posterior petals curved slightly backward, diverging at an angle of 30°, extending less than two-thirds the way to the margin; outer poriferous zones convex, inner nearly straight; interporiferous zones little wider than poriferous zones in medial part, equal near the ends. Pores conjugate. Peristome oval, labiate behind, farther forward than the apical system. Periproct terminal, above the margin, pear-shaped. Peripetalous fasciole without lateral sinuations, slightly bent backward at the anterior end and more strongly bent backward at the posterior end. Subanal fasciole heart-shaped, enclosing a spread-wings-shaped escutcheon, which is

studded with large tubercles arranged in transverse lines and perforated by at least six pores on each side. All four paired interambulacral areas studded with large tubercles within the peripetalous fasciole; nearly bare elsewhere on the upper surface; studded with large, evenly spaced tubercles on the lower surface. Plastron resembling fish scales.

Length, about 56 mm.; width, 50 mm.; height, about 22 mm.

Occurrence.—FLORIDA: Chipola River ¼ mile above bridge at Marianna (holotype, C. W. Cooke, collector).

GEORGIA: Flint River at mouth of Kinchafoonee Creek above Albany (station 7121, C. W. Cooke, collector; station 5054, L. W. Stephenson and Otto Veatch, collectors); Flint River at Bainbridge (station 7097, C. W. Cooke, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 498984.

Remarks.—*Eupatagus curvus* differs from *E. ocalanus* in its incurving posterior petals, the shape of its peripetalous fasciole, and the distribution of its large tubercles.

EUPATAGUS (PLAGIOBRISSUS) OCALANUS Cooke, n. sp.

Plate 6, figures 4–8

Test large, oval, truncated behind; upper surface rostrate above the periproct, sloping to the rounded margin; lower surface nearly flat but projecting downward where the subanal fasciole crosses the median line. Apical system slightly in front of the center; four genital pores, close together; madreporite extending behind the posterior pair of ocular pores. Anterior ambulacral area not at all petaloid, flattened. Petals slightly depressed; anterior pair extending four-fifths the way to the margin, diverging at an angle of 135°; posterior pair longer, extending three-fourths the way to the margin, diverging at an angle of 47°. Poriferous zones about as wide as interporiferous zones; pores elliptical, conjugate. Peristome large, elliptical, labiate behind, slightly farther foward than the apical system. Periproct large, terminal, supramarginal, pear-shaped. Peripetalous fasciole without indentations but having a V-shaped projection above the periproct. Subanal fasciole heart-shaped, enclosing a spread-wings-shaped escutcheon studded with large tubercles arranged in transverse lines. Sternum covered with somewhat smaller tubercles. Posterior ambulacral areas almost smooth on lower surface. Paired interambulacral areas on lower surface covered with a coarse reticulation of large tubercles. Large tubercles on upper surface confined within the peripetalous fasciole, arranged in zigzag rows in the posterior paired interambulacral areas, fewer and more scattered in the other interambulacral areas.

Length, 67 mm.; width, 56 mm.; height, 28 mm.

Occurrence.—FLORIDA: Taylor County rock pit, 1 mile north of Mayo, Lafayette County (type, Florida Geol. Survey I-2406, G. M. Ponton, collector).

GEORGIA: Bainbridge (station 13611, A. F. Foerste, collector).

ALABAMA: Railway cut ¾ mile north of Drewry, Monroe County, upper bed (station 6719, C. W. Cooke, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 372884.

Remarks.—*Eupatagus ocalanus* differs from *E. dixie* in its much wider poriferous zones, its flattened anterior ambulacral area, and in the more plainly zigzag arrangement of its tubercles. Its petals are proportionately longer and narrower than those of *E. carolinensis*, which appears not to have attained so great a size. Its petals are of more even width than those of *E. curvus*, and it lacks the group of large tubercles in the anterior interambulacrai areas.

Subgenus BRISSOPATAGUS Cotteau, 1863

Brissopatagus COTTEAU, *1863*, Congrès sci· France, sess. de Bordeaux, p. 143.
Brissopatagus DUNCAN and SLADEN, *1884*, Palaeontologia Indica, ser. 14, vol. 3, pt. 3, fasc. 3, p. 226.
Brissopatagus POMEL, *1833*, Classification méthodique et genera des échinides, p. 32.
Brissospatangus COTTEAU, *1886*, Paléontologie française, Échinides éocènes, t. 1, pp. 128, 135.
Brissopatagus LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 7, p. 491.

Genotype, *Brissopatagus caumonti* Cotteau, 1863, from the late Eocene of Biarritz, France, designated by Cotteau (1886, p. 135, footnote). This species has been figured by Cotteau (1886, pl. 30).

Brissopatagus, as here interpreted, is characterized by four genital pores close together

with the madreporite behind them; anterior ambulacral area more or less depressed, with inconspicuous pores; anterior petals widely spreading, curved forward, in broad shallow depressions extending into the anterior interambulacral areas; posterior petals nearly straight, diverging at an angle of about 45°, in broad shallow depressions extending into the posterior paired interambulacral areas; peripetalous fasciole little indented, enclosing large tubercles; subanal fasciole enclosing an escutcheon; peristome semilunate, with a posterior lip; periproct large, pear-shaped. So many of these features are identical with those of *Plagiobrissus* that, like it, *Brissopatagus* should be regarded as a subgenus of *Eupatagus*, with which it agrees in apical system, fascioles, peristome, periproct, general character of the ambulacral areas, and in the presence of large tubercles within the peripetalous fasciole. The interporiferous zones of both *Plagiobrissus* and *Brissopatagus* are much narrower than those of *Eupatagus valenciennesii*, the type of the genus. *Brissopatagus* is further distinguishable by its anterior depression, a tendency to be truncated anteriorly, which brings the highest part of the test in front of the apical system, and by the broad depressions on the petals.

EUPATAGUS (BRISSOPATAGUS) GEORGIANUS
Cooke, n. sp.
Plate 7, figures 8–11

Test large, ovate (posterior end wanting); upper surface tumid, highest in front of the apical system, thence descending steeply to the rounded margin; lower surface nearly flat. Apical system in front of the center; four genital pores, the madreporite extending behind them. Petals medium-sized, about equally long, in shallow, broad depressions that extend into the adjacent ambulacral areas; anterior pair widely diverging; interporiferous zones somewhat wider than poriferous zones; front poriferous zones of anterior pair narrower near the apex. Anterior ambulacral area depressed from near the apical system to the peristome; pores inconspicuous. Peristome large, strongly labiate, farther forward than the apical system. Large perforated tubercles in the depressed parts of the paired interambulacral areas, seven or more adjacent to the posterior petals and two or more in front of the anterior petals. Fascioles obliterated.

Original length, about 54 mm.; width, 52 mm.; height, 27.5 mm.

Occurrence.—GEORGIA: Power plant on Kinchafoonee Creek north of Albany (station 10507, C. W. Cooke and T. M. Prettyman, collectors); Flint River below mouth of Cedar Creek, Crisp County (station 7113, C. W. Cooke, collector).

Geologic horizon.—Late Eocene, Ocala limestone.

Type.—U. S. Nat. Mus. 498982.

Remarks.—This species is represented by only two specimens, from both of which the posterior end is broken. Besides the much larger size, which may not be diagnostic, this species is distinguishable from *E. alabamensis* by its wider interporiferous zones.

EUPATAGUS (BRISSOPATAGUS) ALABAMENSIS
Cooke, n. sp.
Plate 4, figures 7, 8

Test small, cordate, highest point in front of the apical system, thence sloping steeply forward. Apical system in front of the center; four genital pores, very close together; madreporite behind the pores. Paired ambulacral areas petaloid; petals and adjacent parts of the interambulacral areas sunken in broad oval depressions; petals extending more than halfway to the ambitus, nearly straight, the posterior pair a little longer than the anterior pair; anterior pair widely diverging; pores large, nearly equal, conjugate; interporiferous zones nearly as wide as the poriferous zones; front poriferous zones of anterior pair narrow near the apical system. Anterior ambulacral area slightly depressed; pore pairs oblique, very small, obsolete distally. Peripetalous fasciole slightly arched toward the apex between the petals; subanal fasciole present. Peristome semilunate, with an anterior lip; located at the anterior third. Periproct high up on the truncated end. Two large crenulated tubercles beside each posterior petal and one in front of each of the anterior pair. These latter single tubercles do not occur on another specimen from the same place. Secondary perforated tubercles border the anterior ambulacral area and decorate the anterior marginal part of the lower surface and the sternal and episternal plates. Elsewhere the

surface is covered with close-set miliary tubercles.

Length of crushed holotype with margin broken, 38 mm.; width, 38 mm.; height, 9 mm. A less distorted specimen from station 10043 measures: length, 35 mm.; width, 32.5 mm.; height, 11 mm.

Occurrence.—ALABAMA: Base of St. Stephens Bluff on Tombigbee River, Washington County (type, station 12168, C. W. Cooke, W. H. Monroe, and R. B. Stewart, collectors); 1½ miles southwest of Perdue Hill, Monroe County (station 10043, C. W. Cooke and Julia Gardner, collectors; station 15064, F. S. MacNeil, collector); 3½ miles southeast of Cullomburg (station 7203, bed 4 of section in U. S. Geol. Survey Prof. Paper 95, p. 116, C. W. Cooke and W. C. Mansfield, collectors); 2 or 3 miles southeast of Whatley, Clark County (station 2957, Frank Burns, collector).

Geologic horizon.—Late Eocene; Ocala limestone and Jackson group (contemporaneous).

Type.—U. S. Nat. Mus. 498979.

Remarks.—This species differs from *B. caumonti* as figured by Cotteau (1886, pl. 30) in that its anterior furrow is shallower and more even; its paired petals are longer and straighter; and its posterior petals, as well as the anterior pair, lie in broad depressions. *Brissopatus alabamensis* appears to have fewer and larger tubercles than are shown on Cotteau's figure, but Cotteau says (1886, p. 137) that the tubercles and fascioles are not visible on his specimen. Presumably his figure is to some extent synthetic.

EUPATAGUS? (BRISSOPATAGUS?) PRIMUS Cooke, n. sp.

Plate 4, figures 1–4

Test cordate; upper surface high, highest point in front of the apical system; anterior margin deeply cut by a rounded sulcus, which slopes steeply from a point in front of the apical system to the peristome. Apical system nearly central, with four genital pores. Petals in broad depressions; anterior pair longer than the posterior, extending nearly to the margin, straight, widely diverging, nearly closed; pores round, conjugate; zones equally wide distally, but interporiferous zones and front poriferous zones narrowing more rapidly than the back poriferous zone near the apical system. Posterior petals straight, extending about two-thirds the way to the margin; outer poriferous zones longer than the inner. Pore pairs of the anterior ambulacral area oblique, narrow, crossing the tumid part of the test and becoming much wider apart and replaced by single pores alternating in position in the sulcus. Posterior interambulacral area arched, apparently covered with tubercles and granules. Peristome far foward.

Length (broken), 34.5 mm.; width, 35 mm.; height, about 24 mm.

Occurrence.—GEORGIA: Dr. A. J. Parke's farm on the Americus road 5 miles south of Ellaville, Schley County (station 4033, S. W. McCallie, collector).

Geologic horizon.—Paleocene, Clayton formation.

Type.—U. S. Nat. Mus. 498978.

Remarks.—This species is represented by only one cast of the interior, to which a few fragments of the silicified test are clinging. It was associated with *Echanthus georgiensis* (Twitchell).

Family ECHINOCARDIIDAE Cooke, n. fam.

Test cordate. Odd ambulacral area unlike the others. Poriferous zones of petals composed of wide plates, which are depressed medially along the sutures. Petals terminated apically or crossed by a fasciole.

The fasciole surrounding the apex, which is known only in this family, is commonly called the *internal fasciole*. It is herein referred to as the *apical fasciole* because the adjective internal is misleading.

Genus ECHINOCARDIUM Gray, 1825

Echinocardium GRAY *1825*, Annals of Philosophy, ser. 2, vol. 10, p. 430.

Amphidetus AGASSIZ, *1836*, Soc. sci. nat. Neuchatel Mém., t. 1, p. 184.

Amphidetus AGASSIZ and DESOR, *1847*, Annales sci. nat. (zoologie), ser. 3, t. 7, reprint p. 117.

Echinocardium DESOR, *1858*, Synopsis des échinides fossiles, p. 406.

Echnocardium A. AGASSIZ, *1872*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 109, 349.

Echinospatagus (*Echinocardium*) POMEL, *1883*, Classification méthodique et genera des échinides, p. 28.

Echinospatagus (*Amphidetus*) POMEL, *1883*, idem, p. 28.

Echinocardium H. L. CLARK, *1917*, Harvard College Mus. Comp. Zoology Mem., vol. 36, no. 2, p. 261.

Echinocardium LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 468.

Amphidetus LAMBERT and THIÉRY, *1924*, idem, p. 469.

Genotype, *Spatangus pusillus* Leske, 1778, =*Echinus cordatus* Pennant, 1777, designated by H. L. Clark (1917, p. 261), a wide-ranging species living in water not deeper than 85 fathoms (H. L. Clark, 1917, p. 263). Lambert and Thiéry (1924, pp. 469, 470) unintentionally designated this same species as the genotype of *Amphidetus*, for Agassiz himself identifies *Amphidetus pusillus* Agassiz with *Spatangus pusillus* Leske.

ECHINOCARDIUM CORDATUM (Pennant)

Echinus cordatus PENNANT, *1777*, British Zoology, vol. 4, p. 58, pl. 34, fig. 2; pl. 36, fig. 2 (fide A. Agassiz).
Echinocardium cordatum A. AGASSIZ, *1872*, *1873*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 109, 349, 580, pl. 19, figs. 10–17; pl. 20, figs. 5–7; pl. 25, figs. 27, 28; pl. 33, fig. 6. (Gives additional synonymy.)
Echinocardium cordatum H. L. CLARK, *1917*, idem, vol. 46, no. 2, p. 262.

Occurrence.—Nearly world wide in moderately deep water.

Geologic horizon.—Recent.

ECHINOCARDIUM ORTHONOTUM (Conrad)

Spatangus orthonotus CONRAD, *1843*, Acad. Nat. Sci. Philadelphia Proc., vol. 1, p. 327.
Amphidetus virginianus FORBES, *1845*, Geol. Soc. London Quart. Jour., vol. 1, p. 425, 3 figs.
Amphidetus orthonotus TUOMEY and HOLMES, *1855*, Pleiocene fossils of South Carolina, pl. 2, figs. 1–1c.
Echinocardium orthonotum CLARK, *1904*, Maryland Geol. Survey Miocene, p. 430, pl. 119, figs. 1a–c.
Echinocardium orthonotum CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 213, pl. 97, figs. 2a–c; pl. 98, figs. 1a–c, 2a–c. Contains additional synonymy.
Echinocardium orthonotum SCHOONOVER, *1941*, Jour. Paleontology, vol. 15, p. 92.

Occurrence.—VIRGINIA: Near Coggins Point, James River (type, Michael Tuomey, collector); Chuckatuck, just below mill dam north of village (U. S. Nat. Mus. 116517, M. W. Twitchell, collector); Prince George (U. S. Nat. Mus. 1688, J. L. Bridges, collector).

MARYLAND: Jones Wharf, Patuxent River (Maryland Geol. Survey); Scientists Cliffs, Chesapeake Bay, Calvert County (U. S. Nat. Mus. 153265, W. F. Foshag and James Benn, collectors).

Geologic horizon.—Miocene; Choptank? formation (Maryland), Yorktown? formation (Virginia).

Type.—Probably Acad. Nat. Sci. Philadelphia.

Remarks.—Schoonover (1941, pp. 92, 93) describes a colony of well-preserved individuals of this species at Scientists Cliffs.

ECHINOCARDIUM GOTHICUM (Ravenel)

Amphidetus gothicus RAVENEL, *1848*, Echinidae, Recent and fossil, of South Carolina, p. 4, figs. 1, 2.
Amphidetus ampliflorus MCCRADY in TUOMEY and HOLMES, *1855*, Pleiocene fossils of South Carolina, p. 6, pl. 3, figs. 2, 2a.
Amphidetus gothicus MCCRADY, *1855*, idem, p. 7, pl. 3, figs. 3, 3a–f.
Echinocardium gothicus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey Mon. 54, p. 214.
Amphidetus gothicus LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 470.

Occurrence.—SOUTH CAROLINA: The Grove, Cooper River.

Geologic horizon.—Pliocene?, Waccamaw formation?; possibly upper Miocene.

Type.—Unknown.

Remarks.—There are no identified specimens of this species in the United States National Museum. McCrady's figures very closely resemble *Echinocardium orthonotum*.

Genus LOVENIA Desor, 1847

Lovenia DESOR in AGASSIZ and DESOR, *1847*, Annales sci. nat. (zoologie), ser. 3, t. 8, p. 11 (reprint, p. 116).
Lovenia A. AGASSIZ, *1872*, *1873*, Harvard College Mus. Comp. Zoology Mem., vol. 3, pp. 139, 574.
Lovenia POMEL, *1883*, Classification méthodique et genera des échinides, p. 28.
Lovenia GRANT and HERTLEIN, *1938*, California Univ. (Los Angeles) Pub. Math. and Phys. Sci., vol. 2, p. 135. (Gives additional synonymy.)

Genotype, *Lovenia hystrix* Desor, 1847, =*Spatangus elongatus* Gray, 1845, living from Zanzibar and the Red Sea to northern Australia and Japan (H. L. Clark, 1917, p. 252), by monotypy. This species has been figured by Agassiz and Desor (1847, pp. 1, 16, fig. 16) and by A. Agassiz (1874, p. 575, pl. 19c, figs. 1–4, etc.).

LOVENIA CLARKI (Lambert)

Echinocardium depressum CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 214, pl. 98, figs. 3a–c. Not *Amphidetus depressus* Agassiz, 1847.

Amphidetus clarki LAMBERT, in LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 470.

Occurrence.—FLORIDA: Chattahoochee, Gadsden County, 78 feet above sea level (type, W. H. Dall and Joseph Stanley-Brown, collectors; station 4836, F. G. Clapp, collector; station 3405, T. W. Vaughan, collector; station 7168, G. C. Matson, collector; station 6185, L. W. Stephenson, collector; station 12282, W. C. Mansfield and G. M. Ponton, collectors.

Geologic horizon.—Early Miocene, base of Tampa limestone.

Type.—U. S. Nat. Mus. 164654.

Remarks.—This species is known only from casts of the interior that lack many specific characters. Some of the casts retain circular grooves that appear to mark the location of large tubercles. The occurrence of tubercles removes the species from *Echinocardium* and seems to place it in or near *Lovenia*, which it resembles in shape. The species is much flatter than *Amphidetus orthonotus*, and its petals are not depressed.

LOVENIA? sp.

Hemipatagus sp. COOKE, *1926*, Alabama Geol. Survey Special Rept. 14, p. 292 (list).

Occurrence.—ALABAMA: Conecuh River at Weaver Chute, 2 miles south of McGowans Bridge, Escambia County (station 6753, C. W. Cooke, collector).

Geologic horizon.—Late Oligocene, Chickasaway marl.

Remarks.—The cast of the interior of an echinoid shows marks of tubercles like those of *Lovenia*. If recognizable specimens are found, they should be compared with *Lovenia dumblei* Kew (1917, p. 136, pl. 17, figs. 2a–c), from Mexico.

Genus VASCONASTER Lambert, 1915

Sarsella POMEL, *1883*, Classification méthodique et genera des échinides, p. 28. Not Haeckel, 1879.

Sarsella COTTEAU, *1886*, Paléontologie française, Échinides éocènes, t. 1, p. 101.

Vasconaster LAMBERT, *1915*, Schweizer. palaeont. Gesell. Abh., vol. 41, p. 191 (note), for *Sarsella* Pomel.

Vasconaster LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 466.

Genotype, *Breynia sulcata* Haime, 1853, from the late Eocene of France, designated by Pomel. This species has been described and figured by Cotteau (1886) p. 103, pls. 22, 23, 24, figs. 1–3). It lacks the internal processes (ampullae) that support the large spines in *Lovenia elongata*.

VASCONASTER GREGORYI (Clark)

Sarsella gregoryi CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 155, pl. 72, figs. 2a–d.

Vasconaster gregoryi LAMBERT and THIÉRY, *1924*, Nomenclature raisonnée des échinides, fasc. 6, p. 466.

Occurrence.—SOUTH CAROLINA: Santee Canal.

Geologic horizon.—Probably late Eocene, Santee limestone.

Type.—Am. Mus. Nat. History.

Remarks.—There are no identified specimens of this species in the United States National Museum.

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ADDENDUM

The following species was omitted from my paper (Cooke, 1941) on the Cenozoic regular echinoids.

PSAMMECHINUS CINGULATUS Clark

Psammechinus cingulatus CLARK *1891*, Johns Hopkins Univ. Circular, vol. 10, no. 87, p. 76.
Psammechinus cingulatus CLARK, *1915*, U. S. Geol. Survey Mon. 54, p. 63, pl. 22, figs. 2a–i. Includes additional synonymy.

Occurrence.—New Jersey: Timber Creek.

Geologic horizon.—Early Eocene, Vincentown sand.

Type.—Acad. Nat. Sci. Philadelphia 1467.

PUBLISHED BY PERMISSION OF THE DIRECTOR OF THE GEOLOGICAL SURVEY.

JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 1, PP. 63–77, PLS. 9–12, 1 TEXT FIG., JANUARY 1942

THE PERMIAN ALGAL GENUS MIZZIA

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ABSTRACT—The genus and the several known species are described and the literature reviewed and discussed. Well-preserved material from New Mexico and West Texas furnished the basis for additional information on certain structural features. A new species, *Mizzia minuta*, is described.

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INTRODUCTION

The algal genus *Mizzia* is recognized in Europe as a significant and often a diagnostic element of the Upper and Middle Permian faunas in a number of stratigraphically important regions, notably the *Bellerophon* faunas of southeastern Europe. It has also been reported from Japan and parts of Asia Minor in beds of equivalent age. Although the genus has previously been reported from North America (Pia, 1937–1940; Johnson, 1938), there exists in the American literature no general review of the genus nor any detailed studies of the American specimens.

HISTORY AND LITERATURE

The genus *Mizzia* was established in 1907 by R. J. Schubert for a fossil collected from dolomites and limestones, then considered of Carboniferous age, in the Paklenica region of the Velebit Mountains, northern Dalmatia. A comparison with Silurian algae described by Stolley (1896) from the Baltic Provinces led to the conclusion that the Dalmatian fossils belonged to the same group, the "Siphoneae verticillateae," related to the modern Dasycladaceae. No formal description of the genus was furnished, no dimensions were given, and the fossil was not figured.

In 1908, in a second and more complete report, Schubert published a brief generic description and named a single species, *Mizzia velebitana*. The specimens described and figured were derived from the Paklenica region, presumably from the same formation and localities as those described in the previous paper.

Later in the same year, Karpinsky (1908) published descriptions of *Mizzia velebitana* from the "*Schwagerina* limestone" of Kinsho-azan, Japan. The paper contains measurements of several specimens and more detailed information relating to the structure of the alga than had Schubert's two articles. In addition to the species already established by Schubert, Karpinsky described a second, *Mizzia japonica*, based on a difference in the ratio of height to width and on certain differences in the number and dimensions of the protuberances and in the size of the polar openings.

Girty, in "The Guadalupian fauna," 1908, described and illustrated a fossil which he named *Guadalupia?* sp., classifying it tentatively among the Spongiae, although he made and rejected the suggestion that it might be a calcareous alga. Ozawa, in 1925, recognized the identity of the form with *Mizzia* and corrected the determination in his synonymy for the type species. Girty published but one measurement for the fossil, which was from collections made in the Guadalupe Mountains, New Mexico.

Negris, in 1915 and in an appendix published in 1919, mentioned the presence of abundant *Mizzia* in limestones of Upper Carboniferous age in Greece but added no

new information relating to structure, dimensions, or relationships. Many of his specimens were submitted to Pia for identification, and photographs of them are included in the work.[1]

Jablonszky (1918), in a discussion of the "Carboniferous Algae of Hungary," reported the occurrence of *Mizzia velebitana* in the Bükke Mountains of Hungary, where it is associated with *Macroporella bellerophontis* and two new unnamed forms. No measurements or illustrations are furnished.

Pia, in 1920, published a detailed revision of the genus with a discussion of the structure and genetic relationships, accompanied by measurements and illustrated by reconstructions and drawings from polished sections. His conclusions with respect to the significance of certain structural features differed from those of Karpinsky and Schubert.

Pia maintained the species *M. velebitana* Schubert but considered that Karpinsky's *M. japonica* was not well founded, probably falling within the limits of variability of the original species. Karpinsky established a new species, *M. yabei*, which included *Stolleyella? yabei* Karpinsky and *Stolleyella velebitana* Karpinsky (not Schubert). *M. yabei* was based on a specimen from the "*Schwagerina* limestone" of Japan, although it occurred also in the Dalmatian collections.

[1] The present authors have some question as to whether Negris' figure 59, p. 215, is in reality a *Mizzia*. The object illustrated has a solid center, and the material composing the center is continuous with that forming the toothlike projections around the circumference. In a characteristic transverse section of *Mizzia*, the wide central cavity is usually clearly differentiated in thin section from the calcareous walls and from the calcareous areas between the radially arranged cavities left the branches. Moreover, slight differences in the shape of the toothlike projections mentioned above distinguishing the fossil from a characteristic *Mizzia*, lead to the suspicion that the section may be that of some other unidentified fossil. Negris does not state by whom this particular specimen was identified. The illustration, a photograph of a polished section, is not sharply defined, and an examination of the specimen itself would be necessary to make a final determination.

Pia (1937) indicated that he doubted the correctness of Negris' determinations of fossils illustrated in the latter's plate 26, figures 3, 4 of the 1919 appendix. Evidently these specimens were not among those submitted to Pia for identification for the earlier paper.

These studies were based on old collections and contained no additional information on stratigraphic position or distribution.

Ozawa (1925) enumerated the localities within the Permo-Carboniferous limestones of Nagato, Japan, where *Mizzia* occurs and corrected Girty's classification of *Guadalupia?* sp. He was the first to assign definitively the enclosing strata to the Permian, stating that the fossil occurs in the "Permian *Fusulina* limestone."

Ogilvie Gordon (1927) reported occurrences of both *Mizzia velebitana* and *Mizzia yabei* from the uppermost horizons (*Bellerophon* limestone) of the Upper Permian in the western Dolomites, Austria. Her specimens agreed with the published descriptions of the original material, which she studied also. Her descriptions add no information to that furnished by Pia in 1920. Both species are figured, but dimensions are given only for *M. velebitana*.

Pia, in 1937, rejected Ogilvie Gordon's determination of *Mizzia yabei*, stating that the fossil erroneously identified by her as *M. yabei* was in reality *Atractyliopsis*. He also expressed doubts that her figures for *M. velebitana* represented that species.[2]

In 1927, in his stratigraphic studies of the *Fusulina* limestone of Akasaka, Ozawa referred to the fact that Yabe had noticed the abundance of *Mizzia velebitana* in the *Neoschwagerina globosa* zone. Ozawa also reported the presence of *Mizzia japonica* in the upper part of the *Neoschwagerina margaritae* zone.

Pia (1927) proposed to classify the fossil Dasycladaceae into broad groups or "tribes" and placed *Mizzia* in the tribe Cyclocrineae, subtribe Cyclocrinineae, immediately following the first genus in that group, *Coelosphaeridium* Roem. The two species, *M. velebitana* Schubert and *M. yabei* (Karpinsky) were maintained by Pia in this work. He also stated that recent studies indicated that the genus is restricted to the Permian, although it had previously been believed to be a Carboniferous form. The text is illustrated with a reconstruction of the type species, *M. velebitana*.

[2] After an examination of Ogilvie Gordon's figures, the present authors concur in these doubts.

Heritsch (1934b) reported *M. velebitana* from the *Bellerophon* limestone of Zazar and Vrzdenec in Yugoslavia, but furnished no descriptions or discussion, although the fossil was figured. He stated that there can no longer be any doubt that the beds in Velika Paklenica, Velebit Mountains, from which Schubert originally described the species, are of Permian rather than Upper Carboniferous age.

Pia, in 1937, in a review of the more important calcareous algae of the late Paleozoic, discussed the geographic distribution and the stratigraphic position of the type species, enumerating the occurrences reported by various authors. From information available to him at that time, he believed that *Mizzia* attained its greatest development in the middle Permian, probably in upper Saxonian or lower Thuringian time, although occurring occasionally in both upper and lower Permian. It is considered to have been nearly extinct at the end of the Permian. This paper contains the first published reports of the occurrences of *Mizzia* in North America and photographs of some American specimens.

Mizzia japonica is revived by Pia in this study on the basis of the report by Ozawa (1927) that he had found *M. velebitana* and *M. japonica* occupying two different beds in the Akasaka limestone.

Pia mentions also the occurrence in Sumatra of another species of *Mizzia* or a related species, but neither describes nor figures this form. He adds that it may possibly represent a terminal member of the thallus of *M. velebitana*.

Johnson (1938) published an abstract in which he stated that preliminary studies of the algae of the Permian Carlsbad limestone disclosed the presence of *Mizzia*, not previously reported in the American literature on the Permian.

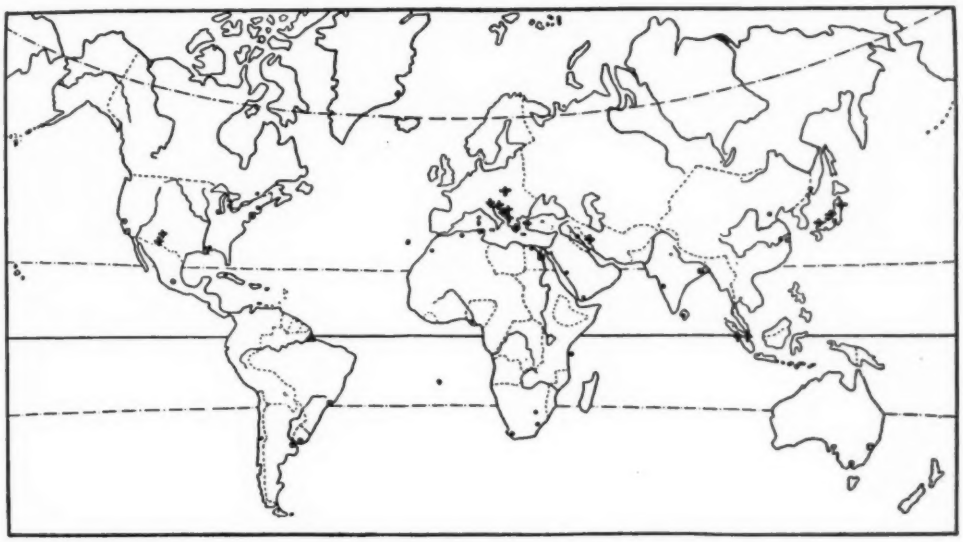


FIG. 1—Geographical distribution of *Mizzia*. (From Pia, 1937, p. 827.)

In a brief notice on the Permian calcareous algae in North America, Pia (1940) notes the presence of *M. velebitana* Schubert in the Carlsbad limestone of New Mexico and Texas.

The present authors studied in detail collections from the Guadalupe Mountains of New Mexico and a smaller collection from the Apache Mountains of Texas. Many of the specimens in these collections were so well preserved as to add to known details of structure and to form the basis for the discussion of structure in this paper. The authors propose a new species, *Mizzia minuta*, described in detail herein.

DISTRIBUTION, RANGE, AND ASSOCIATIONS

Mizzia has been found in widely separated localities in a world-wide, east-west belt extending from the equator north to about the middle of the north temperate zone (fig. 1). In Europe and Asia the belt coincides closely in extent with the areas in which "the *Neoschwagerina* faunas of the Oriental realm flourished in middle Permian time (Dunbar, 1941).

The genus appears to be restricted to the Permian and to have reached the height of its development in the late middle or early upper Permian, although present information is insufficient to make these limits unqualified. The recorded occurrences in New Mexico and Texas are all from the upper Permian.

Mizzia has been found in limestones, dolomites, and calcareous shales. Locally it is so abundant as to form "*Mizzia* dolomites" and "*Mizzia* limestones" (pl. 1, figs. 2, 4). The type species, *Mizzia velebitana*, is apparently everywhere more abundant than the other species except in the New Mexico and Texas localities, where *Mizzia minuta* predominates.

Mizzia velebitana is nearly always closely associated with the alga *Gymnocodium bellerophontis* Rothpletz in the European faunas (Ogilvie Gordon, 1927; Koch, 1933; Heritsch, 1934a–b, 1939), but this species has not yet been recognized in the collections from New Mexico and Texas. Some of the other fossils associated with *Mizzia* in various regions are listed below. Heritsch (1939), in his review of the Carboniferous and Permian of the southern Alps and southeastern Europe, presents additional information on this subject as well as interesting comparisons of the stratigraphically equivalent faunas of these regions with those of Asia Minor and Japan.

DISTRIBUTION, RANGE, AND ASSOCIATIONS OF MIZZIA

Schubert, 1907, Paklenica region, Velebit Mts., north Dalmatia.

In black carbonaceous shales:
Productus semireticulatus
Neoschwagerina craticulifera
Valvulinella sp.
Ammodiscus sp.
"Cornuspira" schlumbergeri
Lunucammina? sp.

In light-colored dolomites:
Neoschwagerina craticulifera
Agathammina sp.
Ammodiscus sp.
Climacammina sp.
Nummulostegina sp.

Schubert, 1908, same locality.
In light-colored dolomites:
Neoschwagerina craticulifera
Fusvlina sp. ind.
Nummulostegina velebitana
Cornuspira sp.
Glomospira sp.
Climacammina sp.

In dark shales and limestones:
Neoschwagerina craticulifera
Valvulinella
Cornuspira incerta
Glomospira gordialis
Glomospira aff. *milioides*
Glomospira aff. *pusilla*
Hemigordius schlumbergeri

Karpinsky, 1908, Kinsho-azan, Akasaka, near Ogaki, Province of Mino, Japan.
In compact, dense, dark-gray limestone with much surface weathering ("*Schwagerina* limestone"):
No associates; absence of *Schwagerina* noted.

Girty, 1908, Capitan Peak, Guadalupe Mts., Texas.
In highest fossiliferous horizon, Capitan limestone:
Fusilina elongata
Sponges

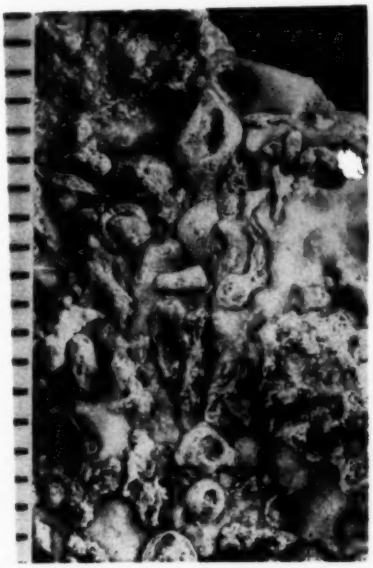
Negris, 1915, Othrys, Parnes, Citheron, continental Greece.
In dark fossiliferous limestone:
Fusilina sp.
Glomospira? sp.
Endothyra panderi

Jablonszky, 1918, Bükke Mts., Hungary.
In black bituminous limestone:
Macroporella bellerophontis

Ozawa, 1925, Akiyoshi limestone district, Japan.
In "Permian *Fusilina* limestone":
Hemigordius japonica
Glomospira sp.
Textularia sp.

EXPLANATION OF PLATE 9

FIGS. *1, 3, 4—Mizzia velebitana* Schubert. *1*, Connected members with finely porous external layer, ×10; detail of *4*. *3*, Connected members in tangential section, ×50. *4*, *Mizzia* limestone, ×0.9. Apache Mountains, Texas. (p. 71)
2—Mizzia minuta Johnson and Dorr, n. sp., forming limestone, ×1, Apache Mountains, Texas. (p. 73)



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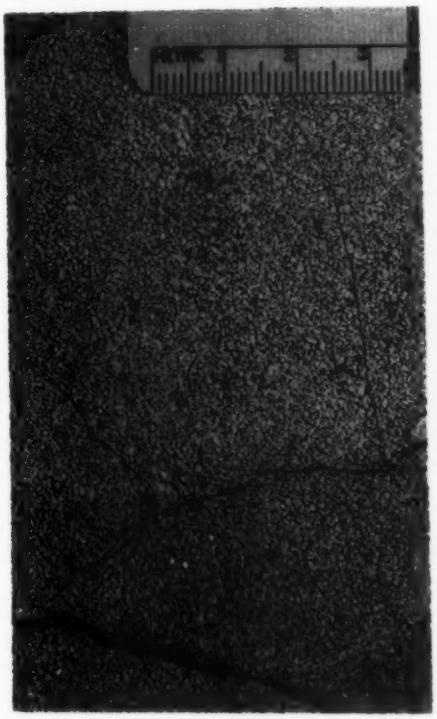

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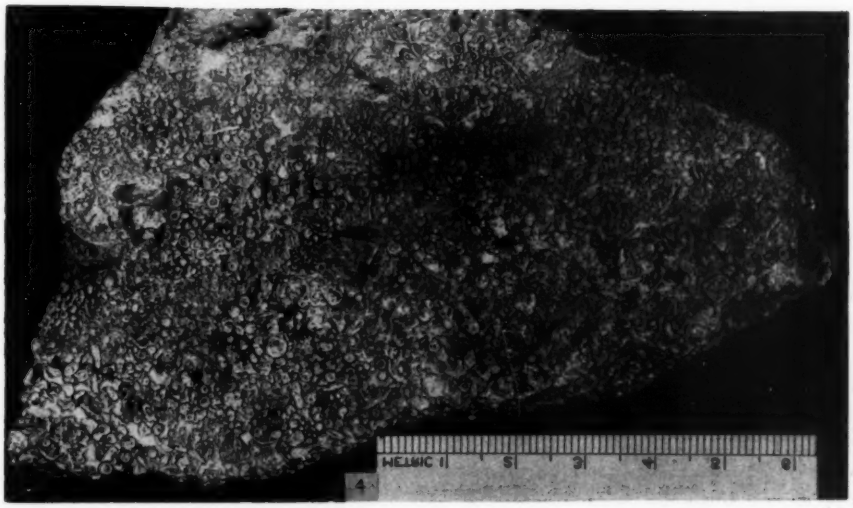
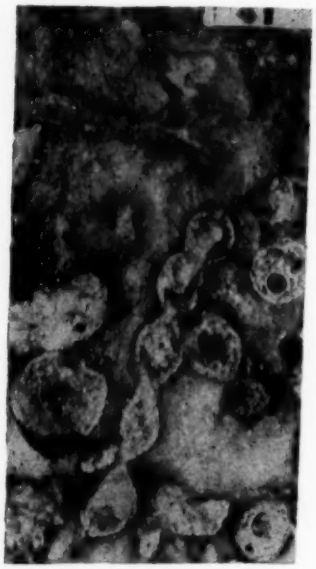


4

Johnson and Dorr, Permian Alga *Mizzia*

1



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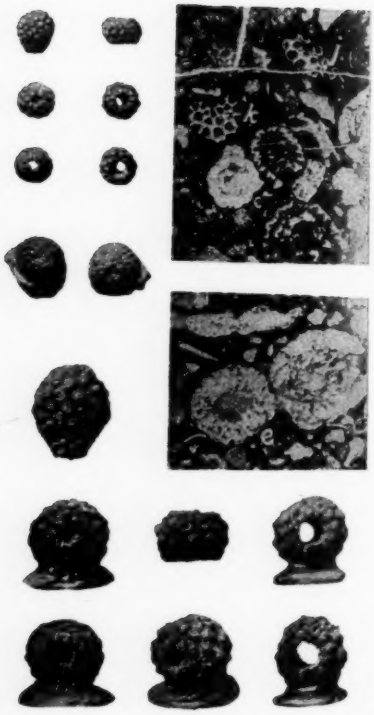

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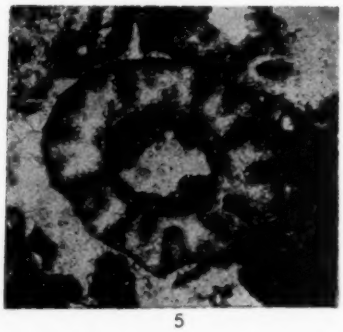

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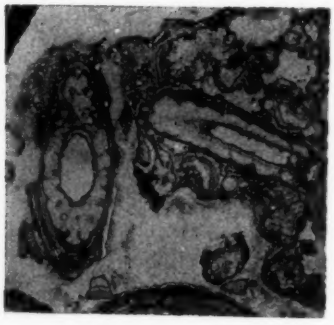


6

Johnson and Dorr, Permian Alga *Mizzia*

Tetrataxis sp.
Fusulinella itoi
Schellwienia sp.
Fusulina sp.
Verbeekina sp.
Doliolina sp.
Neoschwagerina craticulifera
Sumatrina annae

Ozawa, 1927, Akasaka region, Japan.
In black massive limestone with well-preserved fossils; zone of *Neoschwagerina globosa*, including:
Neoschwagerina katoi
Neoschwagerina minoensis
Lonsdaleia (*Waagenophyllum*) *akasakensis*
In dark limestone:
Neoschwagerina margaritae
Verbeekina verbeeki
Fusilina cf. *japonica*

Koch, 1932, Niksicska Zupa, Montenegro.
In black *Bellerophon* limestone:
Bellerophon sp.
Murchisonia n.sp?
Euomphalus sp.
Entalis n. sp.?
Archaeocidaris (isolated spines)
Ostracod remains
Gymnocodium bellerophontis
Gymnocodium nodosum
Vermiporella velebitana
Neoschwagerina sp.
Hemidiscus sp.
Glomospira sp.
Cornuspira sp.
Depratella sp.
Spiroloculina sp.
Ammodiscus sp.
Cribrostomum sp.
Bigenerina sp.
Geinitzina sp.
Textularia sp.

Simic, 1933, Zmajevacbach, western Serbia.
In upper faunal zone of upper Permian limestones:
Edmondia permiana
In middle faunal zone:
Productus sp.
Tschernyschewia sp.
Marginifera sp.
Lyttonia sp.
In lower faunal zone:
Waagenophyllum indicum
Notothyris sp.

Heritsch, 1934b, Zazar, Yugoslavia.
In *Waagenophyllum indicum* bed of upper Permian limestones:
Gymnocodium bellerophontis
Stenopora ovata
Stafella sp.
Waagenophyllum indicum
Notothyris dieneri

Heritsch, 1934b, Somi, Yugoslavia.
In stratigraphically highest beds (limestone):
Gymnocodium bellerophontis
Nodosinella digitata
Climacammina lagenalis
Bigenerina sumatrensis
Productus richthofeni

Johnson, 1938, near White's City, near Carlsbad Caverns, N. Mex.
In Permian Carlsbad limestone.

Pia, 1940, Guadalupe and Delaware Mts., New Mexico and Texas.
In Capitan limestone and lagunal Carlsbad limestone facies.

Yabe, 1940, Upper Paleozoic of Kitakami area, Japan.
In upper division of Maiya series, black slate and local limestone lenses:
Condonofusiella aff. *paradoxica*
Parafusulina sp.
Verbeekina sp.
Yabeina sp.
Waagenophyllum indicum

Johnson, 1941, Guadalupe Mts., NE ¼ sec. 16, T. 22, R. 26 E., west-southwest of Carlsbad, N. Mex.
In limestone containing other Algae.

Johnson, 1941, about 1 mile from mouth of Dark Canyon, southwest of Carlsbad, N. Mex.
In gray limestone containing other Algae.

Johnson, 1941, Slope north of White's City, N. Mex., NE ¼ sec. 34, T. 24 S., R. 25 E.
In dolomitic limestones containing other Algae and Bryozoa.

Johnson, 1941, Walnut Canyon, E. side sec. 28, T. 24 S., R. 25 E., New Mexico.
In dolomitic limestones containing other Algae and fusilinids.

Johnson 1941, Apache Mts., near Seven Heart Gap, Texas.
In dolomitic limestones containing other Algae, brachiopods, Bryozoa, and a trilobite fragment.

GENETIC RELATIONSHIPS

In his 1907 paper Schubert concluded that

EXPLANATION OF PLATE 10

FIGS. *1*, *6*—*Mizzia yabei* (Karpinsky). *1*, From Pia, 1920, p. 23. *6*, Tangential section, ×50, Walnut Canyon, Guadalupe Mountains, New Mexico. (p. 75)

2, *3*, *5*—*Mizzia velebitana* Schubert. *2*, Chain of connected members, ×8, Apache Mountains, Texas. *3*, Restoration, from Pia, 1920, p. 19. *5*, Transverse section, ×50, characteristic abraded specimen, Walnut Canyon, Guadalupe Mountains, New Mexico. (p. 71)

4—Reproduction of Karpinsky's illustrations of *Mizzia velebitana* (nos. 1, 3, 4, 6, 7) and *Mizzia japonica* (nos. 2, 5).

Mizzia were fossil Dasycladaceae related to the modern genus *Bornetella* and to Stolley's Silurian genus *Coelosphaeridium*. In 1908 he again stressed this relationship, stating his belief that *Mizzia* resembled *Coelosphaeridium* F. Roem. in its outer appearance and the form of the canals which radiate from the central cavity toward the outer surface and *Apidium* Stolley in the size of the central cavity.

Karpinsky (1908) at first compared the genus to *Sycidium*, but agreed with Schubert, after a study of the Dalmation forms, on the probable relationship to Solley's genera, stating that *Mizzia* particularly resembled *Apidium*. He also believed that the structure of the test of *Mizzia* showed it to be closely related to the Triassic Siphoneae.

Pia (1920) believed that the hypothesis of a direct, phylogenetic relationship between *Coelosphaeridium* and *Mizzia* was sufficiently well founded to stand until further evidence should be afforded by studies of Devonian Dasycladaceae. This opinion was further illustrated in 1927, in his contribution to Hirmer's Handbook of Paleobotany, when he placed both genera in the same tribe and subtribe.

Succeeding authors have accepted the classification of the genus among the Dasycladaceae and have added no new contributions to its relationships.

DESCRIPTIONS AND STRUCTURE

Schubert originally described *Mizzia* in 1907 as:

> . . . spherical . . . forms, not organized into individual members, with richly faceted surfaces. These may be recognized in thin section as numerous, coarse, in part, irregularly expanded pores, radiating from a central cavity.

An enlarged description appears in his 1908 article:

> Generally spherical, although somewhat tapered toward the lower part, so that the isolated form has a *Lagena*-like appearance. Particularly well preserved specimens show small convex opercula covering the polyhedral to hexagonal surface cells, hence, in most cases the surface appears to be delicately faceted . . . .
>
> . . . The stalkcell is large, nearly spherical and the primary verticillae which radiate from it are pouch-shaped with irregularly alternating lumen expanded toward the base and opening on the surface with polyhedral to hexagonal cross-sections. The convex opercula mentioned above evidently represent the calcified coronal membranes of the surface cells.

Karpinsky's description of the Japanese forms is more detailed. He observed that the outer form might be ellipsoidal (elongated or flattened) as well as spherical and noted the presence of a single opening at each end (pole). The test is described as being covered with small protuberances, of varying dimensions, arranged only rarely in a definite pattern, and compressed by crowding into irregularly rounded or polygonal (usually hexagonal) outlines. Within the test walls, he observed radially arranged pouch-shaped cavities, open toward the interior of the common central cavity and closed at the exterior, each cavity or chamber corresponding to a protuberance on the outer surface. Only when the summit of the protuberance had been destroyed or abraded did the test walls appear to be traversed by canals open at the exterior. No clear statement is made relating to the probable position of the spores or sporangia in *Mizzia*, although from Karpinsky's analogy with the Recent Dasycladaceae it is possible to infer that he considered it probable that they were formed in the branches of the first order.

Jablonszky (1918) reported that some of the Hungarian specimens of *Mizzia velebitana* tapered down to a long stalk. He suggests that many such stalks or stems grew out from a common center, and that the algae probably formed "rosettes" on the floor of the *Productus* sea. The feature is not illustrated in his paper, and no further descriptive details are given. No other investigators have observed this structure, and nothing similar was encountered in any of the specimens from New Mexico and Texas.

Pia, in his 1920 revision of the genus, defined it briefly as " . . . chains of Coelosphaeridia linked together like a string of beads," adding that a common axis united several (probably even many) of the units. His formal description of the genus follows:

> Dasycladaceae with thallus composed of several members joined together. . . . pores unbranched, increasing in size toward the exterior. The spores were most probably produced in the stalkcell.

The occasional presence of a thin membranous crust, distinct from the true massive test of *Mizzia*, is noted by Pia in his general discussion of the calcareous skeleton of fossil Dasycladaceae. In the study of the

type species of the genus *Mizzia*, he states that the development of the calcareous test varies from a thin layer covering all the internal organs (the stalkcell as well as the proximal parts of the verticillae) to a layer thick enough to extend toward the interior as far as the stalkcell. There are all degrees of transition between these two extremes.

Pia is in agreement with Karpinsky in believing that the verticillae are arranged without recognizable pattern, have a marked expansion toward the outer surface, and, in consequence of mutual flattening, have a somewhat polygonal section in their distal parts.

Pia also noted that the pores in the equatorial region are arranged approximately perpendicular to the central axis or very slightly at an angle to it. Toward the upper polar opening, the pores rapidly increase their angle of inclination until they are nearly parallel to the central axis and, at the same time, diminish in length and cross section. In the region of the lower central opening, the pores incline only slightly toward the axis of the thallus.

The greatest diameter of the stalkcell is stated by Pia to be in the equatorial region. From this region it gradually tapers off toward the polar openings.

Pia concluded that the thallus was unbranched, basing this conclusion on the fact that he observed no specimens with two openings on one side. No specimens had been noted which could be taken with certainty to represent a terminal member, that is, a member with only one polar opening. He believed it improbable that the terminal member remained permanently open at the top.

In contrast to both Schubert and Karpinsky, Pia believed that the pores might be either open or closed at the outer surface, the condition depending on the stage of development of the plant and perhaps on the amount of light received by it. The fact that both open and closed pores may occur in the same transverse section is explained by Pia on the ground that the very mobile spherical members of the plant were not buried in the sediments at the place of growth.

Pia also believed it possible that all the widely varying differences in the skeleton may be due wholly or in part to differences between the upper and lower parts of the same plant, suggesting that the specimens with complete calcification of entire space between the cortical layer and the axial cavity originate in the basal part of the alga.

He stated that he had observed no traces of reproductive structures in *Mizzia*, and that it is probable that the formation of the spores took place in the stalkcell. He believed that this condition may have existed in other fossil Dasycladaceae until Cretaceous times, when spores began to be developed in the branchlets, and considered that this fact may explain the relatively large size of the stalkcell of the fossil forms compared to that of modern members of the group.

The authors of the present paper found that the specimens from New Mexico and Texas presented certain previously little known features. They formed conclusions with respect to the interpretation of these features which differed from those of some of the previous authors. These conclusions will be stated under the systematic descriptions.

METHODS OF STUDY AND TERMINOLOGY

The fossils were examined in thin section and in hand specimen. In all nearly 200 thin sections and approximately twice that number of hand specimens were examined. The specimens from the Guadalupe Mountains were studied primarily in thin section because of the small size and abraded condition of the predominant species, *Mizzia minuta*. Thin sections of the Apache Mountains specimens were examined, but several of the hand specimens from this region showed *Mizzia* in such excellent state of preservation that the main emphasis was placed on these specimens.

The symbols used in the tables of measurements in the section of Systematic Descriptions are selected from those used by Pia (1920) with the addition of two from Høeg (1932). They are listed in tabular form below, an asterisk denoting those taken from Høeg.

SYMBOLS FOR MEASUREMENTS

D. Outer diameter of calcareous body
d. Inner diameter of calcareous body
p. Diameter of branches (pores of other authors)
h. Distance between centers of verticillae
st. Diameter of axial cavity (stalkcell of other authors)

*i. Distance between center of branches (pores) on surface
*s. Thickness of calcareous wall

It is evident that it is important to use sections which are approximately equatorial for measurements of *D* and *d*. Care should be taken to attempt to determine the orientation of the section in making measurements as a tangential section may give a false impression of differences in structure and relative dimensions.

It is believed that too great reliance should not be placed on the measurements as indicating the true dimensions of the calcareous parts of the living plant, because many of the specimens were worn and abraded to a greater or less extent before being buried in the sediments. This statement applies particularly to the specimens in the thin sections from the Guadalupe Mountains. Many of these specimens were covered with a banded coating under which the original outlines of the calcified parts of the alga are indistinct. Moreover, considerable abrasion had probably taken place before the plant received the coating.

The terminology of the different authors who have studied the genus varies, particularly with respect to the terms used to describe the radially arranged, symmetrical cavities within the calcareous wall and the central cavity itself. Schubert (1907, 1908) and Karpinsky (1908) used the terms canals and central cavity, the latter making a distinction between the canal and its opening at the summit of the external protuberances in the form of a pore. Girty (1908) used the word pore to designate the canals in the wall, but enclosed it within quotation marks in one place. Pia (1920), in his descriptions of *Mizzia* species, used exclusively the terms pore and stalkcell (Stammzell), although both in his general discussions of the structure of the fossil Dasycladaceae and in his descriptions of other genera of the group he used at times pores and at others branches.

A similar lack of uniform usage appears to prevail among some of the authors who have studied other fossil Dasycladaceae. Høeg (1932), describing Ordovician forms, used the term pore whereas Morellet and Morellet (1913), in a study of the well preserved Tertiary forms of the Paris Basin, were able to use the same terminology as that used in the description of Recent genera.

It would seem advisable that some uniform usage in this respect be suggested and adopted for future work on fossil Dasycladaceae. In view of the well-established genetic relationship with modern forms, it might be proposed that the terminology used in study of the modern genera be adopted for the description of the fossil representatives, in order that precise terms might replace the somewhat vague and varied general terms now in use. The state of preservation of the fossil forms unfortunately does not always permit the identification with complete certainty of the various structures of the plant. Where the preservation has been such as to make possible these distinctions, the appropriate terms have been used, as by Morellet and Morellet (1913). Hence, it seems advisable for the present to continue the use of the generalized terms for the identification of certain structures and the use of the modern terms when the condition of the specimens justifies it.

It is proposed, however, to substitute for the terms pore or canal, neither of which, by dictionary definition or usage, seems particularly applicable to the structure in question in *Mizzia*, the simple term branch; for "stalkcell," axial cavity is suggested. Branch and axial cavity will therefore be used throughout the systematic descriptions and discussion in this paper.

Present information does not permit a complete description or definition of the thallus of *Mizzia*. Pia, in 1920, was the first to recognize that the spherical to pyriform members were united by a single axial cavity. No specimen has yet been found that could be identified with certainty as a terminal member of the plant. With the exception of the long basal stalk reported by Jablonszky (1918), there is no information relating to the basal portion of the thallus or

EXPLANATION OF PLATE 11

FIGS. *1*, *2*—*Mizzia velebitana* Schubert. *1*, Fragment of calcareous wall, ×60; transverse section showing "incomplete calcification." *2*, Enclosing *Girvanella*-like tubules; ×75, Guadalupe Mountains, New Mexico. (p. 71)

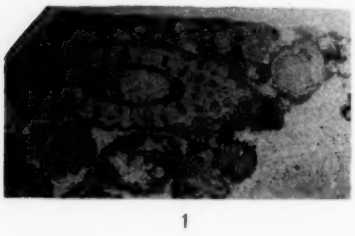
3—*Mizzia* limestone. Details of wall structure, ×7. Apache Mountains, Texas.

1

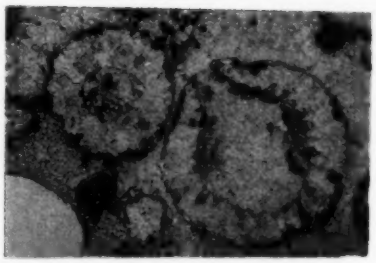
2

3

Johnson and Dorr, Permian Alga *Mizzia*



1



2

3

Johnson and Dorr, Permian Alga *Mizzia*

to its mode of attachment. It seems possible that such structures may have been observed and not recognized when encountered isolated from other parts of the plant or in fragmentary form. Recognition and study must await the time when they are found still attached to one of the members.

"Member," as used in this paper and in previous studies, designates one of the individual, spherical to pear-shaped bodies developed along a single axial cavity. The term is not entirely satisfactory, but the authors are not yet prepared to propose a substitute.

SYSTEMATIC DESCRIPTIONS

Genus MIZZIA Schubert

MIZZIA VELEBITANA Schubert

Plate 9, figures 1, 3, 4; plate 10, figures 2–5; plate 11, figures 1–3

Mizzia SCHUBERT, *1907*, K. k. geol. Reichsanstalt, Verhandl. Wien, no. 8, p. 212.

Mizzia velebitana SCHUBERT, *1908*, K. k. Geol. Reichsanstalt, Wien, Jahrbuch Band 58, Heft 2, p. 382, pl. 16, figs. 8–12.

Mizzia velebitana KARPINSKI, *1908*, Russ. Min. Gesell. Verh., ser. 2, vol. 46, p. 262, pl. 3, figs. 6–9.

Mizzia cf. *velebitana* KARPINSKY, idem, p. 266, pl. 3, figs. 1, 3, 4, 10–13.

Guadalupia? sp. GIRTY, *1908*, U. S. Geol. Survey Prof. Paper 58, p. 85, pl. 5, figs. 7–11.

Mizzia velebitana PIA, *1920*, Zool. botan. Gesell., Wien. Abh., Band 11, Heft 2, p. 19, figs. 12–23, pl. 1.

Mizzia velebitana PIA, *1937*, 2me Cong. Strat. Carbonif. Heerlen 1935, Compte rendu, p. 765, pl. 9, fig. 3.

Mizzia velebitana PIA, *1940*, Akad. Wiss. Wien, Math.-natur. Kl., Sitzungsber.

The description of the original European form may be summarized as follows: Thallus composed of spherical to pyriform members arranged along a single stemlike central axis. Wall of individual members traversed by branches which increase in size as they approach the outer surface of the member.

Dimensions of this species, compiled from all previous studies in which the fossil had been measured, are given below. Dimensions are expressed in the same manner as in the original text from which they were derived.

	SCHUBERT, 1908
Size	1.5–2.2 mm.
Diameter of the surface cells	about 0.1 mm.

KARPINSKY, 1908

In mm.

	1	2	3	4	5	6	7	8
	Fig. 1, 4	Fig. 2, 5					Fig. 13	
Height (length)	1.60	0.96	2.40	1.41	—	0.72	3.20	8.71
Width	1.28	1.40	2.24	1.28	1.12	1.12	—	3.10
Diameter, largest polar opening	0.32	0.57	0.32?	0.48	0.48	—	—	—
Diameter, smaller polar opening	0.25	0.45	—	—	—	—	—	—
Diameter, protuberance	0.22 1)	0.31	—	0.22	0.22 2)	—	— 3)	—

1) Diameter of narrow end of test—0.51 mm.
2) Diameter of narrow end of test—0.8 mm.
3) Amount of displacement —0.53 mm.

EXPLANATION OF PLATE 12

FIG. *1*—*Mizzia yabei* (Karpinsky). Tangential section, ×25. Guadalupe Mountains, New Mexico. (p. 75)

2—*Mizzia minuta* Johnson and Dorr, n. sp. Tangential and transverse sections. ×25. Apache Mountains, Texas. (p. 73)

3—*Mizzia* limestone. Photograph of entire thin section ×7. Abundant fragments of several species of *Mizzia* and other Dasycladaceae. Guadalupe Mountains, New Mexico. (p. 75)

KARPINSKY'S MEASUREMENTS OF SCHUBERT'S DALMATIAN SPECIMENS

Size of test—From 1.0–2.0—2.88 mm.
(Microscope measurements—1.24–2.79 mm.)
Diameter of protuberances—about 0.2 mm.
Thickness of wall in thin section—0.3–0.4 mm. (0.32–0.38 mm.)
Diameter of polar opening—0.48 mm. (only one available)

GIRTY, 1908

Diameter—1½ mm. or less

PIA, 1920

	D	*d*	*st*
1.	1.9	0.9	
2.	2.0	1.1	(equals *st*)
3.	2.6	1.9	1.3

Number of pores in equatorial region—about 20 to 25

OGILVIE GORDON, 1927

1	2
"Small axis of transverse section"	Diameter, central cavity
1.9 mm.	1.0 mm.
2.16 mm.	1.5 mm.
2.5 mm.	1.7 mm.

Some representative dimensions of specimens from the Apache Mountains are given below:

Outer diameter	1.225	1.7500	1.225	1.750	1.6625	1.820	1.8375
Inner diameter	0.8750	1.4800	0.750	1.225	1.225	1.295	1.050
Thickness calcareous walls	0.175	0.1225	0.35	0.263		0.70	0.260
Diameter of pores	4.0775						
Distance between centers of verticillatae						1.750	1.837

The American specimens, particularly those from the collections in the Apache Mountains, Texas, differed in certain characteristics from the description of the European forms. The Texas specimens often have a more nearly pyriform outline, which is usually asymmetrical (pl. 9, fig. 1). The constricted area, connecting two members, is often much longer and slenderer than in the European and Asiatic specimens.

The branches of the Texas specimens appear to terminate at the outer circumference of the member in small rounded protuberances, each containing a small circular opening at the summit. These features correspond to those described by Karpinsky from the Japanese forms but not to the structures observed by Pia in the Dalmatian collections. It is possible that this small opening represents the point at which a hair-like secondary branchlet developed. Examples in which the branches have a wide circular central opening at the outer surface have undergone abrasion, which has worn off the outer and apical portion of the protuberance. The writers, therefore, are of the opinion that varying degrees of abrasion are responsible for the apparent "open pores" described by Pia, rather than different growth stages of the plant, varying environmental conditions, or origin in different parts of the thallus, the various interpretations proposed by Pia to explain this feature.

The shape of the cross section of a branch at the exterior is polygonal, usually hexagonal, and somewhat more symmetrical than is suggested by Pia's (1920) reconstruction. (See pl. 10, fig. 3.) Sections through the branches at intervals successively closer to the axial cavity show them to become more and more circular in outline, indicating that the polygonal form at the exterior is the re-

sult of crowding, as suggested by Karpinsky (1908) and Pia (1920).

In many, if not most of the specimens, the branches (or the protuberances representing their termination at the outer surface) appear to be arranged in roughly regularly alternating rows, resembling a honeycomb pattern. This is in contrast to the observations of both Karpinsky and Pia who described them as only rarely showing a regular arrangement.

A few of the larger specimens of this species have a very finely porous surface, indicating either that the branches in these forms are finer and more numerous than in the majority of the specimens, or that this finely porous region represents a thin outer layer external to the main branches. (See pl. 9, fig. 1.) The present authors believe the latter to be the more probable and that this layer corresponds to the thin membranous layer, distinct from the massive test, mentioned by Pia (1920). A similar structure is described by Morellet and Morellet (1913) who state that this external cuticula is rarely preserved even in the Tertiary specimens which they studied.

In one of the Texas specimens, there is a very well defined rodlike structure within the two upper members, and there are traces of the same or of a similar structure in the lower members (pl. 10, fig. 2). It is believed that this may be the true stalkcell, a separate body, encrusted with calcareous material and entirely filling the axial cavity only at the constricted area between two members. It seems possible that this structure might drop out of the broken thallus after the death of the plant, explaining the fact that the axial cavity is so generally found without it. A somewhat tangential section, appearing on the same specimen above and to the right of the example noted above, shows a very thin calcareous wall or partition within the axial cavity, possibly indicating that the stalkcell received much more delicate calcareous incrustation than the other parts of the alga.[3]

No traces of sporangial chambers were identified by the authors in the Texas collections.

The Texas forms appear to be found in a series of connected members somewhat more often than does *Mizzia minuta*, but this may have been due entirely to accidents of preservation. It is also possible, however, that these specimens may have been found closer to their place of growth than were the specimens from the Guadalupe Mountains.

Occurrence.—Localities 2, 3, 5, 7, 9, 10. Most abundant at 2, 9, and 10.

MIZZIA MINUTA Johnson and Dorr, n. sp.
Plate 9, figure 2; plate 12, figure 2

The specimens of this form from the Guadalupe Mountains agree very closely with the descriptions given for *Mizzia velebitana* by the previous authors with the exception of the smaller size and the smaller number of pores in the equatorial region. They may be described as follows:

Thallus unbranched and consisting of a series of spherical to ellipsoidal members developed along a single axial cavity. Branches undivided, increasing in size from the axial cavity toward outer circumference of member. Shape of member usually very nearly symmetrical and more often spherical than in the American representatives of *Mizzia velebitana*.

Number of branches in the equatorial region from 13 to 16. Branches in the upper portion of the individual member stand almost parallel to the main axis of the plant, those in the equatorial region are more nearly perpendicular to this axis, and basal branches are only slightly inclined toward the axis in a direction opposite from that of the upper branches.

Walls from 0.140 to 0.263 mm. thick. Two

[3] The following passage, translated from the discussion of fossil Dasycladaceae by Morellet and Morellet (1913, p. 8) appears to offer some confirmation of the above tentative conclusions:

The principal stem and the primary branches are barely calcified and consequently rather seldom preserved. The sporangial membranes, on the contrary, are always thickly encrusted; the calcareous material ordinarily fuses them together, not only within an individual whorl but also from one whorl to another and forms a resistant tube, the walls of which are traversed by radial canals, corresponding to the sterile secondary branches, and hollowed by rounded cavities (sporangial chambers) which mark the site of the sporangia. At times this tube is continuous throughout the entire fertile region of the thallus, at others the calcification being interrupted at the level of certain whorls it is divided into distinct segments which are almost always found dissociated.

REPRESENTATIVE MEASUREMENTS OF MIZZIA MINUTA JOHNSON AND DORR (IN MM.)

D	*d*	*st*	*s*	*p*	*i*	No. of equatorial branches
0.875	0.263		0.263			
1.225			0.263			
			0.350			
0.752	0.402		0.437			
			0.175	0.052		14
0.700			0.157	0.087		
			0.140			
0.700	0.665		0.087	0.087	0.157	
				0.122	0.140	
						15
0.962		0.350	0.122			
1.312		0.525	0.157			
0.962	0.350					
0.700	0.490					
0.875	0.437	0.227	0.175			13
0.900	0.350	0.175	0.210			
0.700			0.175	0.035		
0.612	0.385		0.175	0.052		
	0.315		0.140			
			0.122			
0.875	0.408		0.175	0.700		
0.700	0.525		0.152	0.875		
			0.140	0.875		
			0.140	0.105		
			0.122			
0.875	0.437		0.175			16

Average for *D*, 0.795 mm.
Average for *d*, 0.418 mm.

examples showed exceptionally slender walls about 0.085 mm.

The "incomplete calcification" described by Pia (1920, p. 20) is shown in one fragmentary specimen where the area in question has a slight brownish tinge in contrast to the prevailing gray tones of the other parts of the slide (see pl. 11, fig. 1).

In most of the specimens studied, the whole axial cavity is composed of crystalline calcite or, occasionally, of fine-grained calcite and is not divided into a central stem and other parts. This condition might indicate either that the stem of the living alga occupied this entire area or that the walls of this portion of the plant received a very slight calcareous coating during the life of the plant and hence were seldom preserved after its death. The second hypothesis receives some confirmation from the discussion quoted above from Morellet and Morellet, but there is as yet no certain evidence furnished by the American specimens in support of it.

One or two specimens of *Mizzia minuta* from the Guadalupe Mountains showed problematical structures, possibly to be interpreted as sporangial chambers, but a positive statement must be deferred until warranted by further study and better-preserved examples.

A number of the specimens from the Apache Mountains formed a series of connected members, including as many as four and five members, but more often two or three. This may have been due to the fact that the specimens from the region were better preserved than those from the Guada-

lupe Mountains or very possibly because the algae may have been buried closer to their place of growth than were the Guadalupian specimens.

The *Mizzia minuta* from the Guadalupes bore evidences of abrasion and transportation. The physical evidence presented by the appearance of the fossils themselves is further confirmed by the generally accepted belief that the matrix (Carlsbad limestone) in which they are enclosed represents the accumulation of reef debris.

Many fragments and whole transverse sections had received a finely banded, concentric coating covering the exterior and occasionally extending to the inner cavity as well. Some of the banded coatings were composed in part of tubular, filamentous algae allied to *Girvanella;* in others the coating showed no organic structures. In many of the Guadalupian *Mizzia* only the outline of the fossil remains, the internal structures of the wall having been destroyed by recrystallization.

Mizzia minuta is the most abundant species of *Mizzia* in the New Mexico and Texas collections.

Occurrence.—Localities 2, 8–10, 12. Abundant at 2, 9 and 10.

MIZZIA YABEI (Karpinsky)

Plate 10, figures 1, 6; plate 12, figures 1, 3

Stolleyella? yabei KARPINSKY, *1908*, Russ. K. Min. Gesell. Verh., ser. 2, vol. 46, pp. 268, 269.
Stolleyella velebitana KARPINSKY, idem, pl. 3, fig. 8.
Mizzia yabei PIA, *1920*, Zool.-bot. Gesell. Wien. Abh. Band 11, Heft 2, p. 23, pl. 1, figs. 4–6.
Mizzia yabei PIA, *1937*, 2me Cong. Strat. Carbonif. Heerlen 1935, Comptes rendus.

Pia (1920) provisionally united under this name several rare, insufficiently known remains of Dasycladaceae from the upper Carboniferous. The more pertinent features of his description are summarized below:

Elongate-ovate form, almost twice as long as wide. The greatest diameter is found approximately in the upper third of the height. Clear constrictions at the base of the individual members. Most of the branches appear to be closed at the outer surface. In the uppermost part of the member the branches are almost parallel to the central axis, as in *Mizzia velebitana.*

SELECTED MEASUREMENTS OF MIZZIA YABEI FROM PIA (1920)
(In mm.)

	D	*d*
1.	1.0	0.5 mm. (equals *st.*)
2.*	0.5	0.26

* A transverse section which was not cut at the thickest part of the member.

The Guadalupian specimens agree very closely with Pia's descriptions of the European forms in dimensions, most details of structure, and general aspect. No examples of the species were found in the collections from the Apache Mountains.

The following is a revised description:

Thallus unbranched and probably composed of several members developed along a central axis with the limits between individual members marked by a strong constriction. Elongate, elliptical member, about twice as long as wide.

REPRESENTATIVE MEASUREMENTS OF MIZZIA YABEI (KARPINSKY) IN MM.

D	*d*	*s*	*p*
1.120	0.525	0.265	0.052
		0.297	0.087
			0.087
			0.122
0.875	0.315	0.263	
0.910	0.577	0.175	
0.875	0.472	0.210	
0.787	0.437	0.175	
0.700	0.350	0.175	±0.14
		0.263	
0.875	0.472	0.210	

Average for *D*, 0.877 mm.
Average for *d*, 0.449 mm.

Mizzia yabei differs from *M. velebitana* and *M. minuta* in the elongate form of the members, which are smaller than those of *M. minuta.*

The reconstruction (pl. 10, fig. 1) is taken from Pia (1920) and is admitted by that author to be very problematical, since important details of the structure were then unknown.

Transverse sections, particularly those cut in the equatorial region, of *M. minuta* and *M. yabei* must be so similar as to render it extremely difficult to distinguish between them. The same, except for size, is true of *M. velebitana.* It seems possible that a few of the very small transverse sections ob-

served and not definitely classified may represent sections through *M. yabei* at a point within or near the constricted area.

The symmetrical outline of the individual members constitutes a divergence from Pia's forms. Only one of the Guadalupian specimens shows the maximum diameter in the upper third of the member. The statement by Pia is not definitively expressed and it is believed that such minor variations should not prevent reference of these Guadalupian forms to this group.

The branches have a marked expansion toward the outer circumference. Their position is generally perpendicular to the principal axis of the thallus in the equatorial region, with a steeper inclination at the top and a very slight inclination in the opposite direction in the basal portion of the member. As with the other species of *Mizzia* from this region, it is believed that abrasion is responsible for the apparent open termination of the branches at the outer surface. The difficulty of distinguishing between transverse sections of *M. minuta* and *M. yabei* made it impossible to ascertain the number of branches in the equatorial region of the latter with assurance.

The calcareous wall is usually relatively thick and uniform throughout the member. No examples of "incomplete calcification" were observed.

The constricted area between individual members in at least one specimen was rather abrupt, but this appearance may very possibly have been due to breakage; generally it is gradual. No examples were observed in which two entire members were connected by such constriction.

No traces of spore cases or of sporangia were observed.

This form is less abundant and often less well preserved than the other species of Mizzia in the Guadalupe Mountain region. Broken or more or less tangential sections of the upper and lower ends of the individual members are common, and entire members are rare.

Occurrence.—Localities 5 and 9.

MIZZIA JAPONICA Karpinsky
Plate 10, figure 4 (nos. 2, 5)

Mizzia japonica KARPINSKY, *1908*. Russ. k. Min. Gesell., Verh. ser. 2, vol. 46. pl. 3, figs. 2, 5, text fig.

Mizzia japonica OZAWA, *1927*, Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, pt. 3.

Mizzia japonica PIA, *1937*, Comptes Rendus, 2me Cong. Strat. Carbonif., Heerlen 1935.

Karpinsky originally described this species from the specimens sent him from the so-called "*Schwagerina* limestone" of Kinshoazan, Japan on the basis of the following characteristics:

1) Small height, less than the width of the test;
2) small number (4) of the horizontal rows of protuberances;
3) relatively large dimensions;
4) relatively regular arrangement of the protuberances;
5) proportional size of the polar openings.

Pia, in his revision of the genus in 1920, stated that:

> The characteristics on the basis of which Karpinsky separates his *Mizzia japonica* do not appear sufficient to me as the basis for the certain establishment of a new species of calcareous alga. I consider it more probable that they fall within the varieties of *Mizzia velebitana*, principally because probably not all the members of the plant were entirely similar; also Karpinsky's material was not of sufficient quantity to show in a statistical manner that there does not exist any transition between his two species . . . .

In 1927 Ozawa, in his lists of fossils of the *Fusulina* limestone of Akasaka, mentioned *Mizzia japonica* as occurring in the zone of *Neoschwagerina margaritae*, below the *Neoschwagerina globosa* zone in which *Mizzia velebitana* was found.

Pia, in 1937, reported Ozawa's findings and revived the species somewhat tentatively on this ground. However, no one has given a more complete description than Karpinsky.

No examples of the species were found in the collections from New Mexico and Texas.

COLLECTIONS FROM NEW MEXICO AND TEXAS

Guadalupe Mountains, New Mexico

1. Small shallow draw, approximately N ½ sec. 21, T. 22 S., R. 26 E.
2. Draw farthest south in Cueva reentrant of reef (approximately NE ¼ sec. 16, T. 22 S., R. 26 E., Eddy County.
3. Dark Canyon, about 1 mile from mouth.
4. Dark Canyon, about 1½ mile up canyon.
5. Whites' City; slope to north (NE ¼ sec. 34, T. 24 S., R. 25 E.)
6. Whites' City; along old road to Carls-

bad Cavern in NW ¼ sec. 34, T. 24 S., R. 25 E.

7. Walnut Canyon, N. center SE ¼ sec. 27, T. 24 S., R. 25 E.
8. Walnut Canyon, E. side sec. 28, T. 24 S., R. 25 E.
9. Walnut Canyon, NW ¼ sec. 28, T. 24 S., R. 25 E.
10. Carlsbad Cavern (about ¼ mile SW entrance) sec. 26, T. 24 S., R. 24 E.
11. Rattlesnake Canyon.

Texas

12. Well sample from sec. 13, block 35, Univ. Lands, Crane County. (Approx. 20 feet above base of Whitehorse) Snowden & McSweeney #8 University.
13. About 1 mile S. of Heart Gap at northern end of the Apache Mountains.

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MARINE MIOCENE MOLLUSKS FROM CAJON PASS, CALIFORNIA

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ABSTRACT—Two species of mollusks characteristic of the lower Miocene Vaqueros formation, *Turritella inezana* and *Crassatella granti*, collected in Cajon Pass on the north side of the San Andreas rift, are described. This occurrence of marine Vaqueros, 35 miles inland from the nearest locality now known, may represent transgression of the Vaqueros sea across the present Tehachapi Range and southern Mojave Desert.

OCCURRENCE OF FOSSILS

DURING the winter of 1928–1929 L. F. Noble, while engaged in geologic mapping along the San Andreas rift under the auspices of the Geological Survey and the Carnegie Institution of Washington, found marine fossils on the north side of the rift in Cajon Pass at the locality shown in figure 1. The fossils occur in coarse-grained arkosic sandstone overlying comglomerate that rests on granite. Not realizing that *Crassatella* survived as late as Miocene time on the Pacific coast and being misled by the similarity of some of the specimens of *Turritella* to a species from the Martinez formation, I informed Noble that the fossiliferous strata are of Martinez (Eocene) age. (The Martinez formation is now assigned to the Paleocene.) When Loel and Corey's exhaustive monograph of Vaqueros paleontology was published in 1932 it was evident that *Crassatella* survived until Vaqueros time, and that the species from Cajon Pass is a Vaqueros species. It also was evident—and should have been evident from the beginning—that the *Turritella* is the Vaqueros species *Turritella inezana*. In the meantime Remington Kellogg, of the National Museum, visited the locality to examine cetacean remains found in the same strata, remains that would be of extraordinaty interest if they were of Paleocene age. He reported that the remains are too poorly preserved and fragmentary for certain identification but represent evidently a Miocene porpoise.

By 1932 Noble had in press two preliminary accounts of the geology of the San Andreas rift in Cajon Pass that included my early erroneous age identification (Nobel, 1932, 1932*a*). Proofs of the text of both accounts were corrected and the legend of the geologic map in the International Geological Congress Guidebook (Noble, 1932, pl. 3) was likewise corrected. Unfortunately it was too late to correct the lettering on an airplane photograph in that publication (Noble, 1932, pl. 4*b*), on which the strata containing the Vaqueros fossils are designated "Martinez sandstone (Eocene)"—an error for which Nobel is in no way to be held accountable.

The original collection of fossils is at the California Institute of Technology. It includes a fragment of an oyster in addition to the species described. Additional material collected by Remington Kellogg is at the National Museum. Locality data are as follows:

Calif. Inst. Tech. locality 568. Cajon Pass, San Bernardino Co., Calif., spur on southwest side of pass in NE ¼ sec. 34, T. 3 N., R. 6 W., 14,500 feet N. 46° W. from bench mark at Cosy Dell, Hesperia quadrangle. L. F. Noble and W. P. Woodring, February 1929.

U. S. Geological Survey locality 12856. SE ¼ NE ¼ sec. 34, T. 3 N., R. 6 W., Hesperia quadrangle, San Bernardino Co., Calif., about 1½ miles west-northwest of Cajon, altitude 3,700 feet. Remington Kellogg, September 1932.

PALEOGEOGRAPHY

The nearest known marine Vaqueros strata are in the Santa Ana Mountains, the western Santa Monica Mountains, the Ventura Basin, and at the south end of the San Joaquin Valley, localities 35 to 90 miles from Cajon Pass. How the Cajon Pass occurrence is to be reconciled with current conceptions of Miocene paleogeography is not certain. In view of the possibility of horizontal shift of many miles along the San Andreas fault (Noble, 1932*a*, pp. 356–358), the Vaqueros sea may not have

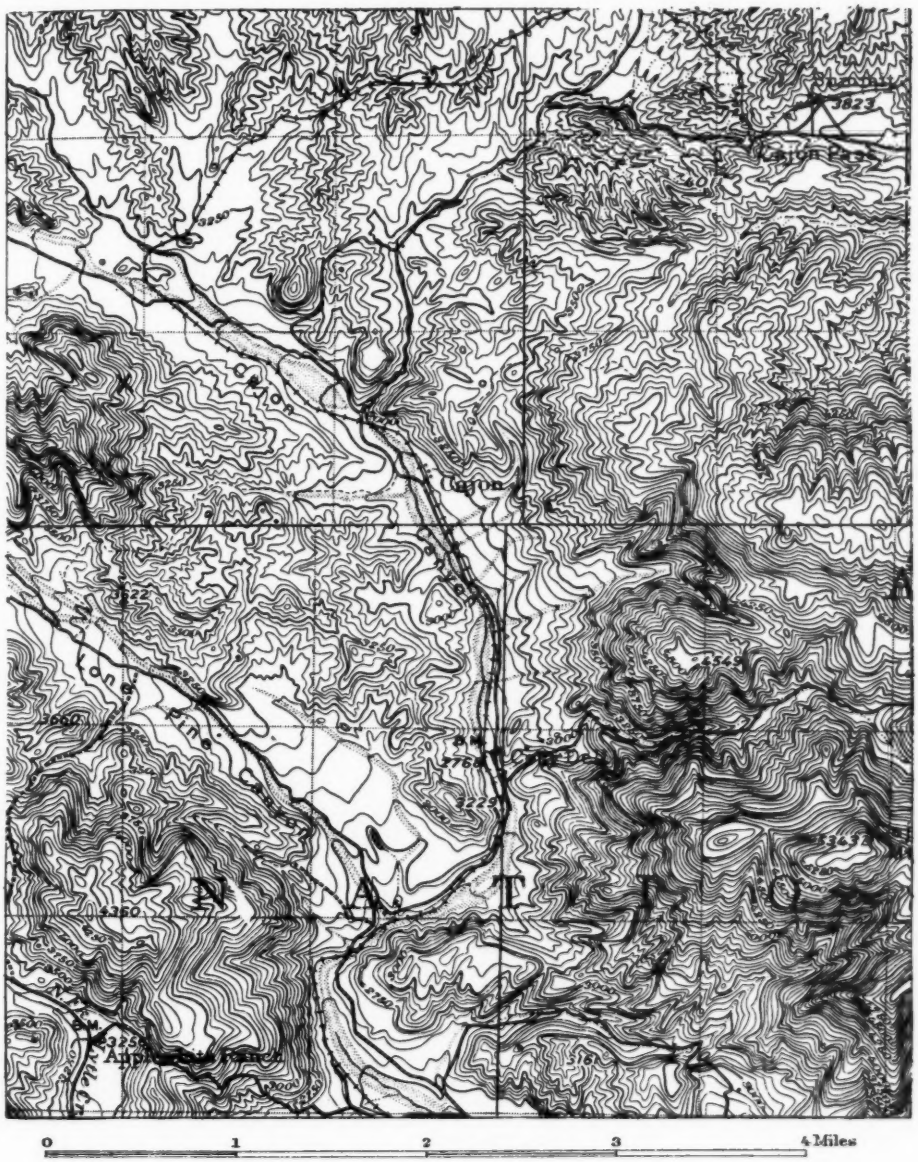

FIG. 1—Southwestern part of Hesperia quadrangle, California (edition of 1902). ×, Fossil locality in Cajon Pass.

penetrated the present site of Cajon Pass. Inasmuch, however, as Vaqueros strata have so far been identified only on the north side of the rift, these strata cannot serve as a stratigraphic test of possible horizontal shift. It may be tempting to link the occurrence of marine Miocene fossils north of the rift in Cajon Pass with the occurrence of marine Miocene fossils south of the rift in San Gorgonio Pass 50 miles to the southeast (Vaughan, 1922, pp. 375–376; Woodring, 1931, p. 13; Bram-

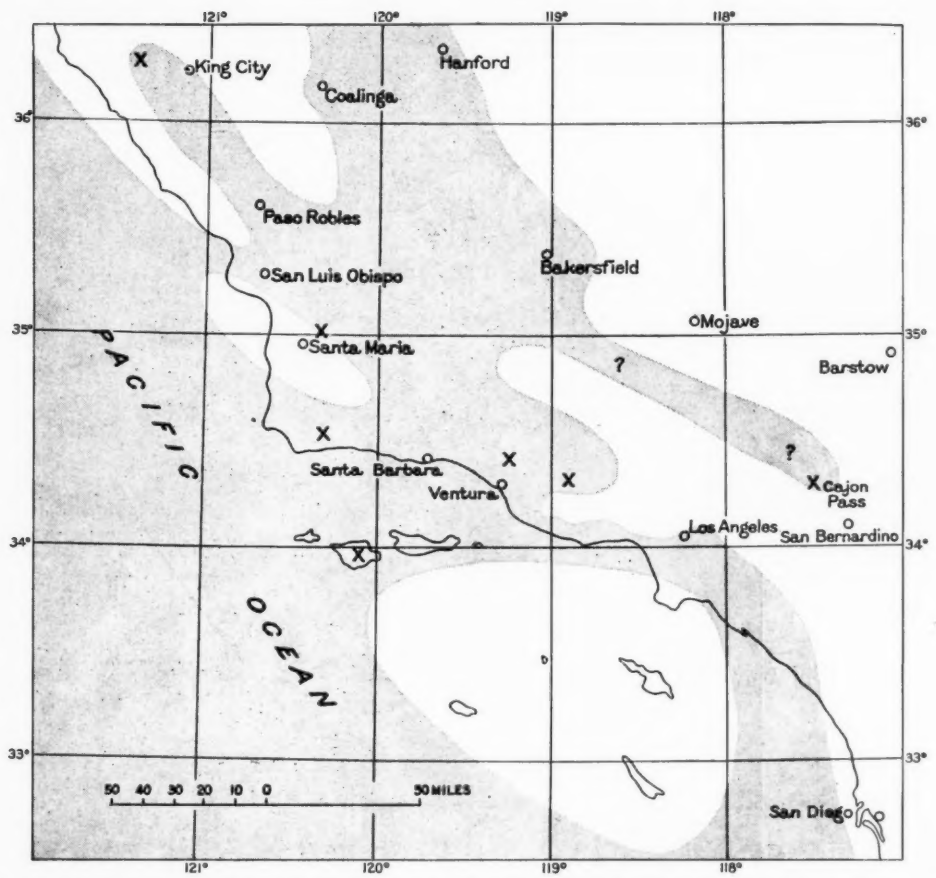

FIG. 2—Map showing inferred distribution of land (blank) and sea (shaded) in southern California during Vaqueros time and localities (×) where *Crassatella granti* has been found. Adapted from Loel and Corey (1932, map 1) and Reed and Hollister (1936, fig. 17).

kamp, 1935). The San Gorgonio Pass marine fossils are found in the Imperial formation and include a *Turritella* (*T. imperialis*) related apparently to *T. inezana*. The Imperial formation represents, however, a Gulf of California faunal province, whereas the Vaqueros formation in Cajon Pass represents a Coast Range faunal province.

EXPLANATION OF PLATE 13

Figures natural size

FIGS. *1, 2*—*Crassatella granti* (Wiedey). *1*, Left valve of moderately elongate paired specimen; length 90.8 mm., height 79 mm., diameter about 45 mm.; California Inst. Technology 3899. *2*, Anterior end of short paired specimen; length about 79.5 mm., height about 80 mm., diameter 49.7 mm., length of foreshortened lunule about 27 mm.; U. S. Nat. Mus. 498963. (p. 82)

3–5—*Turritella inezana* Conrad. *3*, Exceptionally slender incomplete specimen; length 57.7 mm., width 17.7 mm.; California Inst. Technology 3896. *4*, Relatively rapidly enlarging incomplete specimen; length 62.5 mm., width 22.5 mm.; California Inst. Technology 3897. *5*, Large incomplete specimen; length 92.5 mm., width 27.5 mm.; U. S. Nat. Mus. 498961. (p. 81)

1

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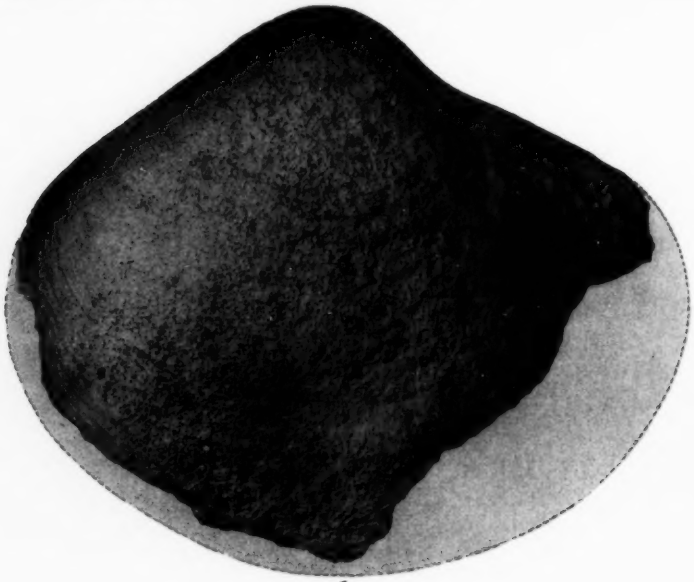
Woodring, Miocene Mollusks



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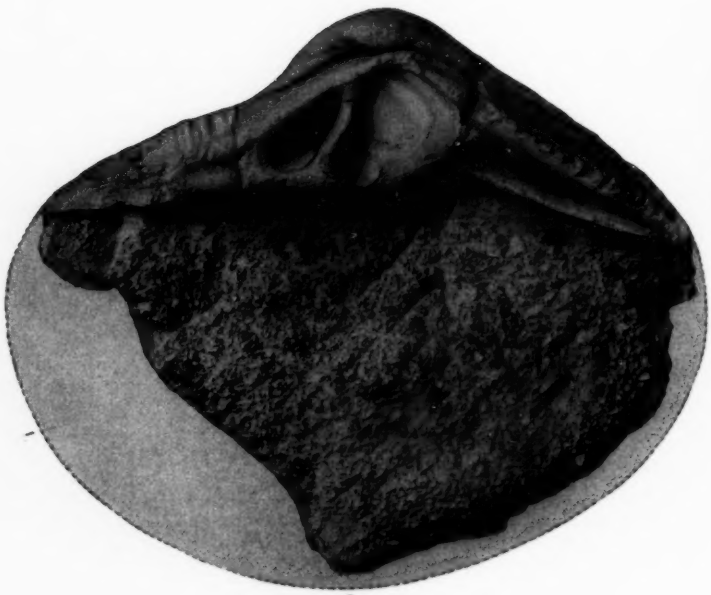

2

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Woodring, Miocene Mollusks

Furthermore, though the Imperial formation is considered Miocene, it is younger than the Vaqueros according to Bramkamp's analysis.

If it be assumed that the Vaqueros sea penetrated the present site of Cajon Pass, a southeastward transgression from the San Joaquin Valley embayment across the present Tehachapi Range and southern Mojave Desert appears to be most probable (figure 2). The apparent absence of the Vaqueros formation south of the rift in and near Cajon Pass suggests that the sea did not transgress from the Santa Ana Mountains across the crystalline rocks of the Perris Plateau. In the eastern Santa Monica Mountains and in the eastern Ventura Basin the marine Vaqueros formation is replaced by nonmarine strata, indicating that the sea did not penetrate the interior from those areas. At the south end of the San Joaquin Valley nonmarine strata underlie marine Vaqueros or are interbedded with the basal marine beds. That the Tehachapi Range was not a barrier during late Miocene time is suggested by the occurrence of marine strata of that age on the south slope of the range, the only locality now known where a marine Miocene formation is found on the border of Mojave Desert. If the range was not a barrier during late Miocene time, it probably was not a barrier during early Miocene time. Regardless of the eventual interpretation of paleogeography, the occurrence in Cajon Pass is an example of the overlap of Vaqueros strata on basement rocks.

DESCRIPTION OF SPECIES

TURRITELLA INEZANA CONRAD

Plate 13, figures 3–5; plate 14, figure 3

Turritella inezana CONRAD, *"1856" [1857?]*, U. S., Pacific R. R. Expl., vol. 7, pt. 2, p. 195, pl. 8, fig. 4.

Turritella inezana ARNOLD and ANDERSON, *1907*, U. S. Geol. Survey Bull. 322, p. 33, pl. 16, fig. 3.

Turritella inezana STEWART, *"1926" [1927]*, Acad. Nat. Sci. Philadelphia Proc., vol. 78, p. 350, pl. 31, fig. 7.

Turritella inezana LOEL and COREY, *1932*, California Univ., Dept. Geol. Sciences, Bull., vol. 22, p. 254 pl. 56, figs. 1, 3–5, 7–9, pl. 57, figs. 8–11, pl. 58, figs. 11, 12.

Turritella inezana MERRIAM, *1941*, idem, vol. 26, p. 105, pl. 23, figs. 1–4; pl. 24, figs. 1, 8–12; pl. 26, fig. 6 (includes illustrations of specimens from Cajon Pass, pl. 24, figs. 8–12).

A large *Turritella* identified as the typical form of *T. inezana*. It is represented by 32 specimens in the California Institute of Technology collection and 17 specimens in the National Museum collection. The largest, consisting of 6½ whorls, the body whorl of which is strongly inflated, has a length of 127 mm. and a width of 34.5 mm. On most of the fossils that have at least some of the early whorls preserved all except about the first six whorls enlarge in width very slowly (pl. 14, fig. 3). A small specimen is unusually slender (pl. 13, fig. 3). Several specimens are exceptional in the relatively rapid rate of increase in width (pl. 13, fig. 4). Details of early sculpture are lost through recrystallization. The sutural collar is stronger on some specimens than on those illustrated. Growth lines suggesting Guillaume's (1924, p. 290) *Turritella imbricataria* group are visible on a few specimens.

The material on which Conrad's description of *Turritella inezana* was based was collected in the Santa Ynez Valley (Antisell, "1856" [1857?], p. 73), presumably not far from the Santa Ynez-Gaviota Pass road. A poorly preserved incomplete specimen of 2½ whorls (length 78 mm., width 32 mm.) in the Conrad collection at the National Museum (13344) bears little resemblance to his poorly drawn figure and does not agree with the dimension cited. Nevertheless when the fossils collected during the surveys for a transcontinental railroad were arranged at

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EXPLANATION OF PLATE 14

Figures natural size

FIGS. *1, 2—Crassatella granti* (Wiedey). Incomplete elongate right valve. Length 89 mm., height 76 mm., diameter about 28 mm. Hinge plate behind middle cardinal restored with plaster paris. Middle cardinal broken and therefore too narrow. U. S. Nat. Mus. no. 498962. (p. 82)

3—Turritella inezana Conrad. Almost complete specimen. Length 99.5 mm., width 22.5 mm. Calif. Inst. Tech. no. 3898. (p. 81)

the National Museum under the direction of C. A. White, this specimen was marked with a green sticker indicating that the arranger thought it was the figured specimen. It was accepted as a neotype by Stewart. The specimen (U. S. Nat. Mus. 165321) from the type region figured by Arnold and Anderson in the publication cited above is a more satisfactory name bearer.

Loel and Corey found *Turritella inezana* proper to be widely distributed and abundant in the Vaqueros formation, particularly in the upper zones. Additional citations for this species may be found in the publications cited above.

Specimens from Cajon Pass that increase in width relatively rapidly resemble a *Turritella*, identified as *T. reversa* (Waring, 1917, p. 88), from the Paleocene Martinez formation of the hills bordering Simi Valley. The Martinez species has, however, a relatively narrow sinus suggesting Guillaume's (1924, p. 286) *Turritella hybrida* group.

Crassatella granti (Wiedey)
Plate 13, figures 1, 2; plate 14, figures 1, 2.

Spisula granti Wiedey, *1928*, San Diego Soc. Nat. History Trans., vol. 5, no. 10, p. 152, pl. 20, figs. 2, 3.
Tivela? vaquerosensis Wiedey, *1929*, Jour. Paleontology, vol. 3, p. 288, pl. 33, fig. 1.
Crassatellites granti Loel and Corey, 1932, California Univ., Dept. Geol. Sciences, Bull., vol. 22, p. 207, pl. 35, pl. 36, fig. 2.

A large thick-shelled *Crassatella* of variable outline, represented by 10 specimens (8 paired) in the California Institute of Technology collection and 4 specimens (2 paired) in the National Museum collection. With due allowance for certain and possible distortion, the outline ranges from short-trigonal to elongate-ovate. Loel and Corey's illustrations, representing, however, specimens from different localities, show the same range of variation. The umbonal ridge is so faint that the outline, as indicated by the synonymy, does not suggest a crassatellid. The replaced shell material is too coarsely crystalline to preserve any fine umbonal sculpture. The remainder of the shell shows only exaggerated growth lines. The inner ventral margin, which is finely fluted in *Crassatella*, is not clearly exposed. Incomplete hinges are preserved on two right valves, one of which is shown on plate 14, figure 2, and a left valve. The middle cardinal on the figured right valve is broken and therefore too narrow. An incomplete right valve in the collection of the University of California (31808), collected on Jalama Creek in the Santa Ynez Range, shows the short ligament area of *Crassatella*.

Crassatella granti is the last known survivor on the Pacific coast of a genus that appeared in the Upper Cretaceous, reached a maximum in the Eocene and Oligocene, and survived until the lower Miocene in America and the middle Miocene in Europe. This species is recorded by Loel and Corey at the localities shown on figure 2, where they found it in the middle and upper parts of the Vaqueros. They record it doubtfully from the Oligocene (?) of the Santa Ynez Range. It does not resemble closely other Pacific coast species, which are less elongate or have a more distinct umbonal ridge. *C. deformis* (Heilprin, 1887, p. 117), from the lower Miocene Tampa formation of Florida, the latest species on the Atlantic coast, is more elongate and has a strong umbonal ridge.

Arguments favoring usage of the name *Crassatella* rather than *Crassatellites* have been discussed recently (Stewart, 1930, pp. 134–136).

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Bramkamp, Richard A., *1935*, Molluscan fauna of the Imperial formation of San Gorgonio Pass: (abstract): *Geol. Soc. America Proc.*, 1934, p. 385. (Through the kindness of Dr. Bramkamp and Professor Bruce Clark I have had the opportunity to examine Bramkamp collections and his description of them, which has not been published. His collections are of exceptional interest, as they include many small mollusks not found in the coarse reef facies of the Imperial formation, the only faunal facies so far described.)

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EOCENE AND OLIGOCENE CORAL FAUNAS OF WASHINGTON

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ABSTRACT—Thirty-three new and four old species of corals and one hydrocoralline are considered. The new species are: *Turbinolia quaylei, T. weaveri, Trochocyathus townsendensis, Stephanocyathus holcombensis, Stephanocyathus?* sp., *Caryophyllia blakeleyensis, C. woodmanensis, C. wynoocheensis, Paracyathus* sp. *A, P?* sp. *B, Discotrochus* sp., *Platycyathus?* sp., *Flabellum hertleini, Coenocyathus? hannibali, Archohelia weaveri, Sclerhelia?* sp., *Madracis stewarti, M. crescentensis, Astrangia clarki, Eusmilia bainbridgensis, Colpophyllia reagani, Leptophyllastrea vaughani, Siderastrea washingtonensis, Siderastrea?* sp., agaricid sp., *Balanophyllia washingtonensis, B. fulleri, Dendrophyllia cowlitzensis, Tubastrea nomlandi,* eupsammid sp., *Montipora schencki, Astreopora duwamishensis, A. sanjuanensis,* and *Stylaster milleri. Balanophyllia teglandae* Durham is proposed as a new name for *B. blakeleyensis* Quayle in Tegland (*nomen nudum*).

By a comparison of the fossil coral assemblages with the recent fauna, it is concluded that the middle Eocene Crescent formation had a tropical environment similar to that now at 20° latitude on the Pacific Coast; that the upper Eocene had tropical or subtropical affinities; that the lower Oligocene shale on the Willapa river near Holcomb was deposited in depths of 250 or more meters in a subtropical climate; that the lower Oligocene Quimper sandstone was deposited under subtropical conditions similar to those in the Gulf of California 18° farther south than the fossil occurrence; that the upper Oligocene Blakeley formation had a like habitat although possibly slightly deeper water.

Two new formations of lower Oligocene age, separated by an unconformity, are described. The lower is the Townsend shale, apparently the equivalent of the Keasey formation of Oregon; the upper is the Quimper sandstone, correlating with the type Gries Ranch beds and overlapping older rocks of several ages.

DURING the course of faunal investigation in the Oligocene and, locally, the underlying Eocene strata of Washington, the writer has collected numerous species of corals. As only three species have been noted previously from these strata, and as important climatic inferences can be made from them, the corals are here described in a separate paper.[1]

Dr. John W. Wells, of Ohio State University, has kindly examined most of the material here described and has given valuable suggestions as to generic assignments, for which the author makes grateful acknowledgement.

As the writer, while working on these faunas, has had occasion to note the occurrence of scattered corals throughout the Tertiary of California, it appears probable that investigation will show the presence of a considerable variety of corals not hitherto noted on the Pacific Coast, and that the faunas of Washington are not unique in this respect.

Thirty-four new and four old species are considered. They were found in formations ranging in age from early middle Eocene (Capay) to late Oligocene. Fragmentary material from several localities indicates that numerous species are yet to be collected and described. Of the species referred to, 22 are colonial and 16 are solitary forms.

All of the coral localities except 7162, A-78, A-1810 (=C.A.S. 912), and N.P. 51, occur between 47°30′ and 49° north latitude, 18° to 20° farther north than most corals are found living on the Pacific Coast. The excepted localities are all north of 46°30′ latitude.

The ecology of the recent corals, in certain aspects as least, is better known than that of many marine organisms. Vaughan (1940, pp. 458–464) has recently reviewed the available data and given references. Many genera are limited both thermally and bathymetrically in their recent distribution. Although some of the genera ranging throughout the Tertiary may have had a

[1] Assistance in the preparation of this manuscript was furnished by the personnel of the Works Projects Administration, Official Project No. 65-1-08-62, Unit A-1.

different distribution in the past than in the recent faunas, it seems that the average environment of the fossil assemblage should approximate that of like recent assemblages. Upon this basis, the coral assemblages from the different localities have been compared with similar modern faunas, and the probable past environment postulated. The results of these comparisons are as follows:

MIDDLE EOCENE

Crescent formation.—This formation was considered by Clark and Vokes (1936, p. 856) to be the equivalent of the Domengine Eocene of California. The fossils upon which they made their correlation all came from the same horizon at the type locality of the formation. Elsewhere this widespread formation probably has greater stratigraphic limits, for Berthiaume (1938, p. 495) refers a foraminiferal fauna from one locality to the Capay of California; the writer has found at another locality (A-3280[2]) a coral, *Archohelia clarki* Vaughan? which is very close to a Meganos species; and, in a still different area of supposedly the same formation, are found Turritellas close to type Tejon (upper Eocene) species. Because of these possible age differences, the species from each locality are separately listed.

The biggest fauna is found at locality A-3206, which Berthiaume (1938, p. 495) referred to the Capay. The following species have been found there:

Astrepora sanjuanensis Durham, n. sp.
Colpophyllia reagani Durham, n. sp.
Leptophyllastrea vaughani Durham, n. sp.
Madracis stewarti Durham, n. sp.
Montipora schencki Durham, n. sp.
Agaricid sp.

With the exception of *Astreopora sanjuanensis* and the agaricid, all species are rather common, and *Montipora schencki* occurs in fairly large masses (the largest collected is fragmentary, $7 \times 11 \times 20$ centimeters). Unidentifiable fragments of several solitary corals have also been collected. Small molluscs, orbitoid Foraminifera, Bryoza, brachipods and calcareous algae are abundant.

[2] Unless otherwise noted, all locality and specimen numbers refer to collections in the Museum of Paleontology of the University of California at Berkeley.

At locality A-3212, *Madracis crescentensis* Durham, n. sp., occurs in association with an abundant normal molluscan fauna, on the basis of which Clark and Vokes (1936) correlated the formation with the Domengine stage.

Archohelia clarki Vaughan? and *Turbinolia quaylei* Durham, n. sp., were found at locality A-3280 in a limy nodule containing numerous molluscs and calcareous algae. However, the surrounding black shales are nearly barren of fossils.

All the genera of corals found in the Crescent formation except *Turbinolia* are colonial and normally tropical types. Their present habitat is as follows:

Archohelia. Extinct, close to *Oculina*, which is widespread, usually reefs, tropical.
Astreopora. Pacific, reefs, tropical.
Agaricids. Normally in reefs, tropical.
Colpophyllia. Florida, reefs, absolute minimum temperature 18.15° C.
Leptophyllastrea. Extinct, reefs?
Madracis. Hawaii, etc., 74–459 meters, 10–22.8° C.
Montipors. Hawaii, etc., 0–74 meters, 22.8–25.6° C.
Turbinolia. West Indies, varying depths, tropical.

The above cited data as to distribution are not necessarily complete, but include only readily accessible data. In some cases, the geographical distribution is known to be greater, but coordinated habitat data is not available to the author.

Montipora and *Madracis* occur associated at locality A-3208, with the first the more abundant. This occurrence together is in contrast to that of the recent fauna of the Hawaiian Islands, where they are not associated, *Montipora* living in warmer water and shallower depths, *Madracis* coming in when *Montipora* disappears. From this fact, it is assumed that the environment at this locality must have been near the boundary between the habitats of the two genera. In the recent fauna, this would be near a depth of 74 meters and a temperature of 22.8° C. This is further supported by the normal habitat of the other genera.

The present 20° C. isotherm in winter skirts the tip of the Peninsula of Lower California and has a slight reentrant into

the Gulf. Thus it appears that during the middle Eocene, the thermal environment in Washington at 48° latitude was similar to that now existing more than 28° farther south on the Pacific Coast.

The genera found at the other two localities check this general thermal conclusion for the Crescent formation, but suggest a somewhat greater depth of water.

UPPER EOCENE

In the Duwamish area near Seattle, there is a marine Eocene fauna, which has been correlated by Weaver with the Tejon of California. The species found here include these corals:

Astreopora duwamishensis Durham, n. sp., loc. A-3208.

Balanophyllia washingtonensis Durham, n. sp., loc. A-3208.

Discotrochus sp., loc. A-3207.

Turbinolia weaveri Durham, n. sp., locs. A-3207, A-3208.

Turbinolia weaveri Durham, n. sp., occurs rather abundantly in a thin bed at both localities, suggesting that it may be a good guide fossil for this horizon.

Dendrophyllia cowlitzensis Durham, n. sp., is described from the type Cowlitz formation, which is correlated with the Tejon by Clark and Vokes (1936). *Astreopora* is a colonial coral found in the present tropical Pacific faunas. *Turbinolia* is living in the West Indies. *Balanophyllia* is widespread and among other places is living in Puget Sound. However, the first two genera cited indicate subtropical to tropical affinities.

LOWER OLIGOCENE

Townsend shale.—Along the Willapa river near Holcomb, Washington, glauconitic tuffaceous shales outcrop. These have generally been considered as synchronous with the Keasey formation of Oregon (Schenck, 1928, p. 36). In the latest work touching upon the Oligocene of Washington, Effinger (1938, p. 361) considered the Willapa river shales as representing a deeper-water facies of the Gries Ranch "zone." However, just north of Woodmans Wharf (now called Romona Beach), 8 miles southeast of Port Townsend, Washington, between 60 and 65 feet of grey-black shale is poorly exposed. This shale overlies the Lyre conglomerates with an irregular contact and is in turn overlain with about a 5° discordance by massive-bedded, more or less arkosic brown-weathering sandstone. The shale is well bedded and includes occasional nodular calcareous beds 6 to 12 inches thick. Considerable pyrite is present, often replacing Foraminifera. The name Townsend shale is proposed for this formation, with the type locality as herein described.

Foraminifera are not overly abundant, but the assemblage is similar to that from the Keasey and includes *Plectofrondicularia packardi* Cushman and Schenck. Mollusca are very scarce, but a few poor pelecypods were found, including *Yoldia* n. sp. and *Acila* cf. *nehalemensis* Hanna.[3]

From this scanty evidence, it seems probable that the Townsend shale is the equivalent of the Keasey shale of Oregon.

Quimper sandstone.—The overlying sandstone, everywhere in the Quimper Peninsula, rest unconformably on older rocks. At Woodmans Wharf, it overlies the Townsend shale which, in turn, is underlain by the Lyre conglomerates. The Lyre conglomerates then rest unconformably on a series of basalts and agglomerates correlated with the Metchosin by Weaver (1937, p. 139). However, in a road cut a short distance to the southwest (NE ¼ NW ¼ SW ¼ sec. 27, T. 29 N., R. 2 W.), the author has found *Turritella uvasana* subsp. *olequahensis* Weaver and Palmer in a grey-green limestone lens interbedded in the basalts just below the Lyre conglomerate. That this species is known only from the Cowlitz, upper Eocene, suggests that these beds may be the equivalent of the Cowlitz rather than the Metchosin and restricts the unconformably overlying Lyre conglomerates to a younger age.

Elsewhere this sandstone overlaps on to older rocks. On the southeast corner of the small island in Port Hadlock Bay, it rests on an irregular surface of Eocene basalt. Across the bay, approximately 3150 feet north of the ferry landing on Marrowstone Island, the contact is exposed on the beach, where it rests on foraminiferal middle Eocene shale correlating with basal Canoas

[3] Identified by H. G. Schenck, personal communication.

silt of California according to R. S. Beck.[4] Four and a half miles southeast, on the shores of Oak Bay, (NW ¼ SE ¼ sec. 29, T. 29 N., R. 1 E.), it rests on Eocene basalts with a surface of high relief. On the eastern shore of Kilisut Harbor, Marrowstone Island, the exact basal contact is concealed within limits of about 50 feet (1300 feet north of south boundary of sec. 32, T. 30 N., R. 1 E.), resting on Eocene sandstones.

Two thousand feet farther north, along the beach, the massive bedded sandstone, here about 900 feet thick, is overlain by moderately well bedded sandy shale. A few feet including the contact are concealed. In this section, the overlying sandy shales contain *Turritella porterensis* Weaver, var., and other fossils, indicating an early middle Oligocene age.

For the sandstone discussed above, resting on older rocks of Eocene and Oligocene age and overlain by sandy shales of lower middle Oligocene age, the name Quimper sandstone is proposed, with the 900-foot section on the east side of Kilisut Harbor as type section and the other areas noted above as supplementary sections.

Much of the fauna of the Quimper sandstone has been listed by Effinger (1938, pp. 364–365) from Woodmans Wharf. This fauna is found only at or near the base; higher in the sandstone other elements are present. As he noted, the lower fauna correlates with the type Gries Ranch.

Thus if the fauna of the basal Quimper sandstone correlates with the type Gries Ranch, and the unconformably underlying Townsend shale is the equivalent of the Keasey, the Keasey cannot be the deep-water facies of the Gries Ranch beds, but is an older part of the Oligocene.

Keasey shale.—At the locality previously mentioned on the Willapa river (C. A. S. loc. 912, U. C. Mus. Pal. loc. A-1810), two species of corals were found. They are *Stephanocyathus holcombensis* Durham, n. sp., and *Flabellum hertleini* Durham, n. sp. The *Flabellum* belongs to the *F. pavoninum* group, which inhabits tropical and subtropical waters between 250 and 650 meters, rarely shallower, and in temperatures ranging from 3°–19°C. *Stephanocyathus* is found in tropical and subtropical waters of 200 meters or more depth. It seems probable then that at this locality the depth was over 250 meters, and the surface temperature was at least subtropical.

Quimper sandstone.—At or near the basal contact of the Quimper sandstone in the Quimper peninsula area, corals are usually abundant, although only at Woodmans Wharf are they well preserved. Ten genera have been identified and poor material representing others has been collected in this area. The species are as follows:

Archohelia weaveri Durham, n. sp., locs. A-1802, A-1808.
Astrangia clarki Durham, n. sp., loc. A-1802.
Balanophyllia fulleri Durham, n. sp., locs. A-1802, A-1808, A-3213.
Caryophyllia woodmanensis Durham, n. sp., loc. A-1802.
Eupsammid sp., loc. A-1801.
Paracyathus sp. B. loc. A-1802.
Siderastrea? sp., loc. A-1802.
Stylaster milleri Durham, n. sp., locs. A-1802, A-1808, A-3209.
Trochocyathus townsendensis Durham, n. sp., locs. N. P. 148, A-1802. n. sp.
Tubastrea nomlandi Durham, n. sp., loc. A–1802.

The habitats of the genera listed are as follows:

Archohelia. Extinct, close to *Oculina*, which is widespread in warmer tropical areas, usually reef dweller.
Astrangia. Living on Pacific Coast as far north as San Diego.
Balanophyllia. Widespread.
Caryophyllia. Widespread.
Eupsammid genus. Normally tropical reefs.
Paracyathus. Widespread.
Siderastrea. Tropical, West Indies, Gulf of Guinea.
Stylaster (Hydrocoralline). Moderately widespread.
Trochocyathus. Largely tropical.
Tubastrea. Tropical Pacific.

At locality A-1802 (Woodmans Wharf), the corals occur chiefly in small lenses of conglomerate at the base of the Quimper sandstone, but some species range a few feet higher. They are associated with an exceptionally varied molluscan fauna, abun-

[4] Personal communication, November, 1939.

dant brachiopods, Bryozoa, barnacles, rare Foraminifera, echinoid spines, calcareous algae, leaf fragments and shark teeth. *Balanophyllia fulleri* is very abundant, *Archohelia weaveri* is fairly common, occurring both as heavy massive and as slender branching types, indicating, according to Vaughan, exposure to wave action and sheltered habitats respectively. It is probable that both did not grow together, but that one or both have been washed into their present location. The hydrocoralline *Stylaster* is moderately plentiful also.

The presence of the heavy, massive variety of *Archohelia*, together with numerous *Acmaea*, the terrestrial gastropod *Segmentina*, abundant barnacle plates, leaf fragments and the small lenses of conglomerate indicate that the depth of deposition of the basal bed here was not over 10 meters and probably less. Perhaps the lenses of conglomerate and the few feet of sandstone immediately overlying represent the initial deposits of the advancing Quimper sea. Ten to 20 feet higher stratigraphically, the massive corals and the other indications of very shallow water have all disappeared, and the fauna suggests somewhat deeper water.

The presence of *Archohelia*, *Tubastrea*, the eupsammid genus and *Siderastrea?* suggests that the coral fauna was living in a habitat similar to that now found within the Gulf of California[5] some 18° farther south. It is also to be noted that the Gulf of California is a protected area, and that the same corals are not found farther north than near Cape San Lucas on the outside of the peninsula of Lower California, about 6° farther south than inside the Gulf. This probably represents an average minimum temperature of around 18° C. In this connection, it is interesting to note that fossil wood found at locality A-1801 has been identified by R. W. Chaney[6] as wood of the palm family. The palm *Washingtonia* ranges from Mexico northward into the Colorado Desert of southern California, that is, in areas largely adjacent to the Gulf of California, thus corroborating the environment postulated for the corals.

At localities A-1808 and A-3209, abundant corals are present, but the sandstone, resting on basalt, has been recrystallized and leached, so that few of the corals can be determined. At both places, the associated fauna is similar to that at locality A-1802, except that the massive varieties of *Archohelia* have not been noted, suggesting that perhaps the water was not quite so shallow.

Dendrophyllia hannibali Nomland from N. P. loc. 51 (not 15, a typographical error) is from beds with a fauna that correlates with the Quimper sandstone. It is probable that further search there would reveal the presence of additional species of corals.

Coenocyathus? hannibali Durham, n. sp., from N. P. loc. 207 on Vance creek is from beds that may correlate with either the Townsend shale or the Quimper sandstone. Insufficient work has been done to determine their stratigraphic position, but shales are present in the area with a Keasey-type foraminiferal fauna.

MIDDLE OLIGOCENE

As yet no corals have been found in the Lincoln or beds of similar age. This is probably because these sediments are largely of a slightly deeper facies.

UPPER OLIGOCENE

Blakeley formation.—Seven identifiable species of corals were found in the type Blakeley; all except *Caryophyllia blakeleyensis* Durham, n. sp., occur only in the lower Blakeley conglomerates or belt F of Weaver (1916, pp. 41–52).

The species found are as follows:

Balanophyllia teglandae Durham, n. name, loc. 681.
Caryophyllia blakeleyensis Durham, n. sp., locs. A-1804, A-1807, A-1812, A-3210.
Eusmilia bainbridgensis Durham, n. sp., locs. A-1807, A-3211.
Paracyathus sp. A, locs. A-1804, A-1807.
Platycyathus? sp., loc. A-1812.
Sclerhelia? sp., loc. A-3211.
Siderastrea washingtonensis Durham, n. sp., loc. A–1807.

Other species are represented by fragmentary material inadequate for identification.

The presence of *Siderastrea* and *Eusmilia*

[5] According to Verrill (1871), corals of these types do not occur farther north on the Pacific Coast.

[6] Personal communication, February 2, 1940.

indicates that the lower Blakeley fauna has a subtropical aspect, for neither of these genera is known to live outside of subtropical waters. No coral genera of these types are known to live on the Pacific Coast farther north than the Gulf of California. The lack of many genera found in the Quimper sandstone may indicate either slightly cooler water or a somewhat deeper habitat. Most of the corals are found in conglomerates that may contain boulders up to 2 feet in diameter, but interbedded with the conglomerates are occasional beds as much as 6 inches thick that are composed largely of the crushed tests of spatangoid echinoids, suggesting a moderate depth of water. In addition the associated molluscan fauna does not contain any species limited to an extremely shallow depth.

Sooke formation.—*Siderastrea vancouverensis* Vaughan was described from the Sooke formation, which was considered to be of the same age as the Blakeley by Clark and Arnold. New evidence seems to indicate that the Sooke may be slightly younger. LaMotte (1935, pp. 51–55) reported a florule from the Sooke formation as containing a mixture of temperate and subtropical genera. The presence of *Siderastrea* corroborates the presence of the subtropical plants. A restudy of the recent analogous molluscan species as given by Clark and Arnold for the Sooke fauna suggests that it corresponds to a fauna living off San Francisco, using the method of Keen (1937). However, it should be noted that their list only includes 27 out of 66 species of Mollusca and therefore may be subject to error.

Twin Rivers formation.—A specimen of a colonial coral found in the upper part of the Twin Rivers formation has been identified by Dr. T. Wayland Vaughan[7] as *Siderastrea vancouverensis* Vaughan. As noted above, this genus indicates a subtropical environment.

OLIGOCENE UNDIFFERENTIATED

Caryophyllia wynoocheensis Durham, n. sp., is associated with Oligocene molluscs, otherwise nothing is known of its stratigraphic allocation.

[7] Personal communication, September 18, 1940.

Stephanocyathus? n. sp., is found in an area that is mapped by Weaver (1937) as Oligocene older than Blakeley, otherwise nothing is known of its stratigraphic position.

DESCRIPTION OF SPECIES

Genus TURBINOLIA Lamarck, 1816

Turbinolia LAMARCK (in part) *1816*, Hist. Nat. Anim. sans Vert., vol. 2, p. 229.

Genotype: *Turbinolia sulcata* Lamarck.

TURBINOLIA QUAYLEI Durham, n. sp.
Plate 15, figures 5, 10

Corallum conical, moderately elongate. Calyx circular. Septa in three cycles with corresponding costae. Costae as thick as or thicker than their interspaces, and also thicker than their corresponding septa, in profile shaped like an inverted "U." Apparently a single row of pores in intercostal furrows, but uncertain. Septa wavy, only moderately thin, usually about half as thick as interseptal loculi, moderately granulate, those of third cycle fused to second cycle about one-third of distance from columella. Granules on septal faces arranged in rows, slanting downwards at an angle of 45°, interspaces between the rows as wide as the rows. Columella irregular, solid, projecting slightly from bottom of calyx, but not as high as periphery of calyx.

Diameter of holotype (section near top), 3.00 mm.; length 7.0 mm.

Holotype, no 14795; paratypes, nos. 14796, 14797.

Occurrence: Loc. A-3280.

Geologic horizon: Cresent formation, Eocene.

This species rather closely resembles *T. imbulata* (Hanna) from the Rose Canyon shale, but may be distinguished from it by the U-shaped costae, the lesser number of septal granules, and the thinner septa. The thick costae in three cycles readily separates it from *T. weaveri*, n. sp.

At the type locality, *T. quaylei* occurs in calcareous sandy concretions associated with molluscs, in otherwise rather barren black shales.

TURBINOLIA WEAVERI Durham, n. sp.
Plate 15, figures 3, 4, 13

Corallum conical, stout to elongate. Calyx circular or nearly so. Costae in four cycles, the fourth cycle opposite the interseptal loculi, slightly thinner but equally prominent with the preceding cycles and extending about halfway down the side of the corallum. The first cycle of costae extends to the base, and the second and third cycles successively begin with one-tenth of the total height. Costae prominent, usually extending out twice the thickness of the wall or more, edges granulate. Intercostal furrows all with a single row of pores. Septa in three cycles, only slightly wavy, all cycles apparently equally exsert, lateral surface ornamented with granules in rows inclined sharply downwards. Tertiary septa fused to primaries, which are greatly thickened near the columella. Columella irregular, ending below upper margins of septa.

Length of holotype and paratype, respectively, 7.3 mm., 6.0 mm.; diameter, 3.0 mm., 3.1 mm.

Holotype no. 12420; paratypes nos. 12418, 12563, 12564.

Occurrence: Holotype from loc. A-3207, also from loc. A-3208.

Geologic horizon: Eocene of Duwamish area (equals Tejon *fide* Weaver).

This species may be distinguished from *T. pusillanima* Nomland (1916, p. 62, pl. 3, figs. 9, 10) by the more prominent costae, the greater length of the fourth cycle of costae and by the prominent granules on the septal faces descending in sharply inclined rows, which according to Quayle (1932, p. 102) are not present on *T. pusillanima* Nomland.

Genus TROCHOCYATHUS Milne Edwards and Haime, 1848

Trochocyathus MILNE EDWARDS and HAIME, *1848*, Ann. Sci. Nat., ser. 3, t. 9, p. 300.

Genotype: *Turbinolia mitrata* Goldfuss.

TROCHOCYATHUS TOWNSENDENSIS Durham, n. sp.
Plate 15, figures 6, 9; plate 17, figure 17

Corallum conical, the base being broken off, but with evidence of having been attached. The calyx is subcircular and rather deep. The septa are in four complete cycles with most of the fifth cycle present in the larger specimens, in small individuals, the fourth cycle may be incomplete. The septa are nearly as wide as the interseptal loculi at the wall, wedging out toward the columella. Numerous septal granules present. Pali appear to be in two crowns, in several cycles in the large specimens. Costae present, corresponding to the septa, and are wider than the costal interspaces. The sides of the costae are ornamented with numerous granules. Columella well-developed, composed of numerous twisted processes.

Long and short diameters of calyx: holotype, 18.0 mm., 16.0 mm.; paratype, 5.0 mm., 4.5 mm. Height of corallum: holotype, ±22.0 mm. (estimated); paratype, 7.0 mm. Diameter of corallum just above base of paratype, 2.0 mm.

Holotype, no. L. S. J. U. no. 6765; paratypes, nos. 12421, 12423.

Occurrence: Loc. A-1802, A-1808, N. P. 148.

Geologic horizon: Quimper sandstone, lower Oligocene.

Genus STEPHANOCYATHUS Seguenza, 1864

Stephanocyathus SEGUENZA, *1864*, Corall. Terz. Messina, p. 61.

Genolectotype: *Stephanocyathus elegans* Seguenza (Wells, 1936, p. 131)

STEPHANOCYATHUS HOLCOMBENSIS Durham, n. sp.
Plate 17, figures 15, 18a, 18b

Corallum bowl-shaped, rather large. Septa in four cycles with corresponding costae. Costae die out towards center of base, intercostal furrows slightly wider than costae at periphery. A more or less prominent furrow around periphery next to top of calyx. Septa of first and second cycles highly exsert, those of the first cycle being most prominent and protruding to a height equal to the depth of the calyx. Septa of third and fourth cycles progressively less exsert until fourth cycle is only slightly exsert. Pali present close to columella and of small size, before which cycles not exactly determinable but probably first and second. Columella but poorly determinable,

probably papillose. Surface of septa covered with numerous granules.

Height of calyx of holotype and paratype, 6.0 mm. and 7.0 mm.; diameter, 28.0 mm. and 24.0 mm.; height of septa above calyx ±5.0 mm. and ±5.0 mm.

Holotype, no 12500; paratype, no. 12489.

Occurrence: Loc. A-1810

Geologic horizon: Keasey formation, Lower Oligocene.

STEPHANOCYATHUS? n. sp.

A segment of a large shallow, bowl-shaped coral, probably originally about 30 mm. in diameter, was collected at N. P. loc. 167 by Hannibal. It resembles *Stephanocyathus holcombensis* Durham, n. sp., but the calyx is not nearly as deep and some of the septa have distant serrations on the upper edges. Pali present.

Hypotype: L. S. J. U. no. 6766.

Geologic horizon: Oligocene, older than Blakeley (*fide* Weaver 1937).

Genus CARYOPHYLLIA Lamarck, 1801

Carophyllia LAMARCK, *1801*, Syst. Anim. sans Vert., p. 370.
Cyathina EHRENBERG, *1834*, Corall. des Rothen Meeres, p. 76.
Cyathina MILNE EDWARDS and HAIME, *1848*, Ann. Sci. Nat., ser. 3, t. 9, p. 285.

Genotype: *Caryophyllia cyathus* Lamarck.

CARYOPHYLLIA BLAKELEYENSIS
Durham, n. sp.
Plate 16, figures 11, 15

Corallum broadly conical, enlarging rapidly from the base. The calyx is elliptical, broad, and shallow. The septa are in five cycles with granulated costae corresponding to all cycles. The costae of the first, second, and third cycles are of equal size, those of the fourth and fifth cycles progressively smaller. The outside of the corallum is somewhat worn, but apparently the costae were not very prominent except near the calyx. Pali are present before the third or fourth cycles. The septa of the first, second, and third cycles are evenly exsert, the fourth cycle slightly and the fifth cycle just barely exsert because of the angle of slope down to the fourth cycle, thus the top of the calyx has a serrated appearance.

The columella and pali appear to have projected slightly above the floor of the calyx, with the columella compressed in the direction of elongation of the calyx.

Height of holotype, 15 mm.; long diameter of calyx, 16 mm.; short diameter of calyx, 13.5 mm.; smallest diameter of corallum, 6 mm.; height of smallest diameter above base, 4 mm.

Holotype, no. 14789.

Occurrence: Holotype from loc. A-1807, also from locs. A-1804, A-3210, A-1812.

Geologic horizon: Lower Blakely formation, upper Oligocene.

The serrated margin and flaring shape of the calyx characterize this species as compared with the two following new species.

CARYOPHYLLIA WOODMANENSIS
Durham, n. sp.
Plate 16, figures 6, 7

Corallum ranging from subconical to subcylindrical, with a broadly expanding base. The calyx is subcircular and not very deep. Costae are usually not visible, but when not covered by epitheca, they are very narrow and sharp, corresponding to the septa. The epitheca may extend nearly to the top of the corallum and is of irregular thickness. The septa are in five cycles, with pali present before the second and third cycles. The pali are broad, about as wide as the septa of that cycle, and slightly undulated. The septa are slightly exsert, with the first and second cycles projecting the most. The upper margins of the septa are crenulate and slightly dentate. Abundant granules on the septal faces. The columella is trabecular and not as high as the septa.

Height of holotype, 15 mm.; long diameter of calyx of holotype and paratype 10 mm. and 13 mm.; short diameter of calyx, 8 mm. and 10 mm.; diameter above basal expansion of holotype, 6 mm.

Holotype, no. 14748; paratype, no. 14747.

Occurrence: Loc. A-1802.

Geologic horizon: Quimper sandstone, lower Oligocene.

The thin, slightly exsert septa distinguish this species from *C. blakeleyensis* Durham, n. sp., and *C. wynoocheensis* Durham, n. sp.

CARYOPHYLLIA WYNOOCHEENSIS
Durham, n. sp.
Plate 16, figures 10, 14

Corallum broadly conical, enlarging rapidly from a minute point of attachment, which is broken off. Calyx elliptical, broad and apparently shallow. Costae beaded, corresponding to septa, those corresponding to the first and second cycles most prominent and forming minor angulations of the periphery of the corallum. Costae of third and fourth cycles equally prominent. Wall formed by fusion of the septa. Septa in four cycles, first and second reaching the columella, third nearly so, but the fourth cycle only reaching about one-third of distance to columella. Septa occasionally perforate, very heavy towards base, thinner near top of calyx, rare granules. Pali present, character indeterminate because of poor preservation of calyx. Columella formed by irregular fusion of inner edges of septa.

Height of holotype and paratype 16.0 mm. and 23.0 mm.; long diameter of calyx, 14.5 mm. and 16.0 mm. incomplete; short diameter of calyx, 13.0 mm. and 12.5 mm.

Holotype, no. 14783; paratype, no. 14782.

Occurrence: Loc. A-78, Wynooche River, Washington.

Geologic horizon: Oligocene.

The heavy septa will distinguish this species from the two previously described.

Genus PARACYATHUS Milne Edwards and Haime, 1848

Paracyathus MILNE EDWARDS and HAIME, *1848*, Ann. Sci. Nat., ser. 3., t. 9, p. 318.

Genotype: *Paracyathus procumbens* Milne Edwards and Haime

PARACYATHUS sp. A.
Plate 17, figure 16

Several specimens of a solitary coral with an adherent base were found in the basal Blakeley. Septa in four or more cycles, slightly but evenly exsert, lateral surfaces strongly granulated. Costae corresponding to the septa.

Hypotype, no. 12565.

Occurrence: Locs. A-1804 and A-1807.

Geologic horizon: Lower Blakeley formation, upper Oligocene.

PARACYATHUS? sp. B.

A few small fragmentary specimens possibly referable to this genus were found at loc. A-1802, Quimper sandstone, lower Oligocene.

Hypotype, no. 12566.

Genus DISCOTROCHUS Milne Edwards and Haime, 1848

Discotrochus MILNE EDWARDS and HAIME, *1848*, Ann. Sci. Nat., ser. 3, t. 9, p. 251.

Genotype: *Discotrochus orbignyanus* Milne Edwards and Haime.

DISCOTROCHUS sp.
Plate 17, figure 9

A poorly preserved specimen of *Discotrochus* with four complete cycles of septa and part of the fifth was found at loc. A-3207, Duwamish Eocene.

Hypotype, no. 12250.

Genus PLATYCYATHUS de Fromentel, 1863

Platycyathus DE FROMENTEL, *1863*, Paléontolcgie française, Terrain, crétacé, Zoophytes, p. 180.

Genotype: *Trochocyathus terquemi* Edwards and Haime (subs. desig., Wells, 1933).

PLATYCYATHUS? sp.

A poorly preserved specimen of an apparent *Platycyathus* with wavy septa in three cycles, of which the first cycle is slightly more exsert and heavier than the second cycle, while the third cycle is distinctly less exsert, was found at U. C. loc. A-1812, from belt F of the Blakeley formation, upper Oligocene. Diameter about 3 mm. The specimen was lost while in the photographer's hands.

Genus FLABELLUM Lesson, 1830

Flabellum LESSON, *1830*, Illust. de Zool., pl. 14.

Genotype: *Flabellum pavoninum* Lesson.

FLABELLUM HERTLEINI Durham, n. sp.
Plate 15 figures 14, 17;
plate 17, figure 5

Corallum large, somewhat annular in shape, but in reality an extreme expansion of a flabelliform type. The corallum has expanded in greater amounts on the periphery until the lateral edges are touching.

As a result one side of the corallum has been resting on the substratum and is very slightly convex. Pedicel broken off. The calyx is around the periphery and opens slantingly out and upwards. The average width of the calyx is 17.0 mm. As a result of the mode of growth, the upper wall is rather steeply inclined towards the base, leaving a conical crater in the center of the corallum. Minimum angle between the two walls about 45°. Septa straight, not exsert, granulated, about 10 to each 8 mm. on lower wall with apparently an extra cycle of septa present when compared with the upper wall, so that septa on the upper wall are not so closely spaced. Beaded costal ridges, corresponding to interseptal loculi.

Diameter of holotype, 66 by 53 mm.

Holotype: California Acad. Sci. no. 5978; paratype, 14791.

Occurrence: California Acad. Sci. loc. 912 and loc. A-1810.

Geologic horizon: Keasey formation, lower Oligocene.

The paratype is a fragmentary specimen with some suggestions that it did not obtain the complete annular shape of the holotype.

This species is comparable to *F. pavoninum* Lesson, the recent genotypic species, but may be distinguished from it by the annular shape, by scarcer and coarser septal granules, and by the more prominent beaded costae.

Genus COENOCYATHUS Milne Edwards and Haime, 1848

Coenocyathus MILNE EDWARDS and HAIME, *1848*, Ann. Sci. Nat., ser. 3, t. 9, p. 297.

COENOCYATHUS? HANNIBALI Durham, n. sp.
Plate 17, figure 14, text figure 1

Corallum composite, adherent, corallites united at base to wall of an older individual, at least seven individuals in type colony. Individual corallites tall, slender, tapering to base. Calyx circular, fossula perhaps 2 mm. deep. Costae very slight, corresponding to septa. Septa in four cycles, very thin, pali before first, second, and third cycles, not free. Sides of septa well granulated, pali much thicker than septa, not equally developed. Columella not present unless represented by a single paliform process. First and second cycles of septa equally developed, third nearly as well, and fourth reaching half-way to center of calyx.

Diameter of top of individual corallite

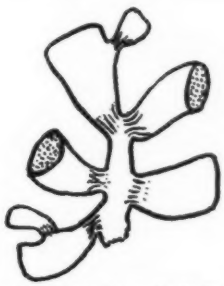


FIG. *1—Coenocyathus? hannibali* Durham, n. sp. Sketch of growth form, ×1½.

±7.0 mm.; length of top of individual corallite ±14.0 mm.

Holotype: L. S. J. U. no. 6767.

Occurrence: N. P. loc. 207, Vance Creek, Washington.

Geologic horizon: Probably equivalent to Keasey as a Keasey foraminiferal fauna is found near there.

Genus ARCHOHELIA Vaughan, 1919

Archohelia VAUGHAN, *1919*, U. S. Nat. Mus. Bull. 103, p. 352.

Genotype: *Archohelia limonensis* Vaughan, orig. desig.

ARCHOHELIA WEAVERI Durham, n. sp.
Plate 16, figures 1–3; plate 17, figure 8

Corallum varying from slender, slightly branching to massive, heavy, tuberous branches with thick, solid coenenchyma, intermediate variants common, massive variety not very common. Corallites usually in rough bands on slender varieties, irregularly disposed on more massive form, where they are usually 6 to 12 mm. apart. Corallite somewhat projecting on slender form, nearly flush to slightly sunken on massive variants. Finely granulated striations sometimes present near the calyces, extremely faint on the massive forms. Calyces vary from 2.0 to 5.0 mm. in diameter, and 2.0 to 3.0 mm. in depth. Septa not exsert, in three complete cycles, usually

with part of the fourth present, the primaries reach the center and fuse to form the columella, later cycles progressively shorter. Columella thickened at upper end, otherwise small. Axial corallite present.

Holotype, no. 12568; paratypes, nos. 12569, 12570.

Occurrence: Loc. A-1802, A-1808.

Geologic horizon: Quimper sandstone, lower Oligocene.

May be distinguished from *A. clarki* Vaughan by the additional cycle of septa, by the average greater diameter of the calyces, by the less projecting calyces, by the lesser diameter of the columella, and by only the first cycle of septa extending to the columella.

The variation in form appears to be due to differences in environment, as Vaughan (1919, p. 196) has noted in the living oculinids that the same species will have slender branches in undisturbed water and strengthened skeletons where exposed to surf and wave action.

ARCHOHELIA CLARKI Vaughan?

At locality A–3280, a number of fragments of a small branching *Archohelia* very similar to *A. clarki* Vaughan (1927, p. 143, pl. 23, figs. 1–5) were found. They occur in a hard calcareous sandy concretion, and the preservation is such that they cannot be examined in detail. All characters observed agree with those of the above cited species, which occurs in division D of the Meganos Eocene of California on the north side of Mount Diablo.

Hypotypes, nos. 12251, 12252, 12400.

Occurrence: Loc. A-3280.

Geologic horizon: Crescent formation, middle Eocene.

Genus SCLERHELIA Milne Edwards and Haime, 1850

Sclerhelia MILNE EDWARDS and HAIME, *1850*, Ann. Sci. Nat., ser. 3, t. 13. p. 75.

Genotype: *Madrepora hirtella* Pallas (monotypy)

SCLERHELIA? sp.
Plate 17, figure 7

Corallum worn, arborescent, moderately heavy, coenenchyma comparatively thin. Calyces large, slightly projecting, apparently very shallow. Septa in four incomplete cycles, septal granules common, pali present. Costae apparently absent.

Height of corallum, 31.0± mm.; diameter of corallum, 10.0± mm.; diameter of a calyx, 7.0± mm.

Hypotype, no. 12562.

Occurrence: Loc. A-3211.

Geologic horizon: Lower Blakeley formation, upper Oligocene.

The reference of this specimen to *Sclerhelia* is very tentative, it does not fit in any of the common oculinid genera.

Genus MADRACIS Milne Edwards and Haime, 1849

Madracis MILNE EDWARDS and HAIME, *1849*, Comptes Rendus, t. 29, p. 70.

Genotype: *Madracis asperula* Milne Edwards and Haime.

MADRACIS STEWARTI Durham, n. sp.
Plate 15, figure. 11

Colony branching, branches circular to polygonal in section, diameter 3.0 mm. to 6.0 mm. Surface between calyces granular to costate. Calyces shallow, subcircular to circular, diameter 1.5 mm. to 2.0 mm., margins rarely slightly elevated, calyces usually 0.5 mm. to 2.0 mm. apart. Septa 10, reaching columella, not exsert, slightly thicker at corallite wall. Septal granules few. Columella styliform, very thick below projecting point, which is nearly flush with surface of branch. Parent corallite filled with a dense internal calcareous deposit.

Holotype, no. 14766; paratype, no. 14765.

Occurrence: Loc. A-3206, east of Port Cresent, Washington.

Geologic horizon: Crescent formation, middle Eocene.

Madracis stewarti, n. sp., is very close to *M. ganei* Vaughan (1900, p. 128) from the lower Claiborne of the Gulf Coast Eocene, but differs from it in having slightly smaller calyces, in the branches being much smaller and the surface more often nearly costate. Further, the calyces are of a more uniform size. This latter character, along with a more prominent columellar style distinguishes it from *M. crescentensis* n. sp.

MADRACIS CRESCENTENSIS Durham, n. sp.
Plate 17, figures 1, 10

Corallum arborescent; numerous subcylindrical flattened branches. Corallites small, very abundant, closely but irregularly disposed on the surface, usually distant from one-half to one diameter from one another; not raised. Diameter of calyces usually from 1.0 mm. to 1.3 mm., calyces rather deep. Septa in two cycles, first cycle better developed than second, usually about ten in number, not exsert. Columella formed by fusion of septa of first cycle, terminating in a small tubercle.

Branches from 6.0 mm. to 10.0 mm. in diameter, length at least 10 to 14 cm.

Holotype, no. 14763; paratype, no. 14764.

Occurrence: Loc. A-3212, Port Crescent, Washington.

Geologic horizon: Crescent formation, middle Eocene.

This species may be distinguished from *M. stewarti*, n. sp., by the much more closely crowded, slightly smaller and deeper calyces, with a less prominent columellar style, and the larger and heavier branches.

Genus ASTRANGIA Milne Edwards and Haime, 1848

Astrangia MILNE EDWARDS and HAIME, *1848*, Comptes Rendus, t. 27, p. 496.

Genotype: *Astrangia michelinii* Milne Edwards and Haime.

ASTRANGIA CLARKI Durham, n. sp.
Plate 15, figure 7; plate 17, figure 12

Moderately short corallites united by a common encrusting basal expansion, bases nearly touching one another. Well-marked costa corresponding both to septa and the interseptal loculi. Near top of corallite alternating rows of granules present on the costae; near the base, they merge into a single row. Intercostal furrows about half as wide as costae. Calyx subcircular, rather deep. Septa in three complete cycles successively less prominent than preceding. Fourth cycle when present just barely projecting from wall. Septal margins sparsely dentate. Columella composed of a a few paliform processes.

Height of three corallites, 4.0 mm., 5.0 mm., 2.0 mm.; diameter, 4.5 mm., 5.5 mm., 4.0 mm.

Holotype, no. 12561; paratypes, no. 12545, 12556.

Occurrence: Loc. A-1802.

Geologic horizon: Quimper sandstone, lower Oligocene.

Somewhat similar to *A. coalingensis* Vaughan (Arnold, 1909, p. 152, pl. 23, fig. 3) but the costal granules are fewer and larger, and the dentation of the septal margins is coarser.

Genus EUSMILIA Milne Edwards and Haime, 1848

Eusmilia MILNE EDWARDS and HAIME, *1848*, Comptes Rendus, t. 27, p. 467.

Genotype: *Madrepora fastigiata* Pallas.

EUSMILIA BAINBRIDGENSIS Durham, n. sp.
Plate 16, figure 13

Corallum adherent, forming a stalk with the calyces near the top. Calyces few; two, three, or four on the specimens observed.

The calyces are irregular in shape, nearly round or elongate, the average diameter is 8.0 mm. A low saddle with a distinct, sharp costal ridge in the center usually separates the calyces. The upper part of the calyces is broken on all the specimens observed, so the details of it are lacking. The septa are heavy, very irregular in shape and disposition, in three complete cycles, with part of the fourth sometimes present. The septa of the long axis of the calyx are best developed. The columella is heavy and compressed parallel to the long axis of the calyx. The upper part of the corallum is ornamented by sharp, well-defined costal ridges, which diminish in size till hardly apparent at half the height of the corallum. They correspond to the septa in number.

Height of holotype, 35.0 mm.; diameter near the base (broken off), 8.0 mm.; diameter below calyces, 11.0 mm.

Holotype, no. 14792.

Occurrence: Locs. A-1807, A-3211.

Geologic horizon: Lower Blakeley formation, upper Oligocene.

E. bainbridgensis, n. sp., may be distinguished from *E. solida* (Nomland) of the Carrizo formation by the sharper, more prominent costal ridges and the heavier columella.

Genus COLPOPHYLLIA Milne Edwards and Haime, 1848

Colpophyllia MILNE EDWARDS and HAIME, *1848*, Comptes rendus, t. 27, p. 492.
Manicina Ehrenberg of authors see: Wells, *1936*, pp. 104, 118).

Genotype: *Madrepora gyrosa* Ellis and Solander, 1786 = *Madrepora natans* Müller, 1775. (*non Manicina gyrosa* Ehrenberg) see: Wells, 1936, pp. 104, 118).

COLPOPHYLLIA REAGANI Durham, n. sp.
Plate 16, figure 5; plate 17, figure 2

Corallum apparently attached by a basal peduncle, lower surfaces slope outwards and upwards, upper surface nearly flat. A large specimen is 12 cm. in diameter. Common outer wall undulatory. Costae abundant, rather sharp, 10 or 11 to the centimeter.

Valleys long and irregular, from 8 to 14 mm. wide, usually around 12 mm. wide, and around 6 or 7 mm. deep. Summit of ridges rather narrow, from 1 to 1.5 mm. wide. Walls of adjacent series coalesced, no separating furrow present.

Septa 12 to 18 to the centimeter, appear to be dentate, of about equal thickness except for occasional irregular, thicker specimens, often every other septa more prominent. Septal faces densely granulate, synapticula irregularly present. The septa slope from the top of the wall into the axial furrow at an angle of about 45°, for a distance of 5 to 7 mm., then abruptly fall off into the furrow. No apparent pali, septa in part apparently nearly meet at bottom of furrow. Faint trabecular columella. Calycinal centers indistinct, apparently linked by lamellae.

Holotype, no. 14779; paratype, no. 14778.

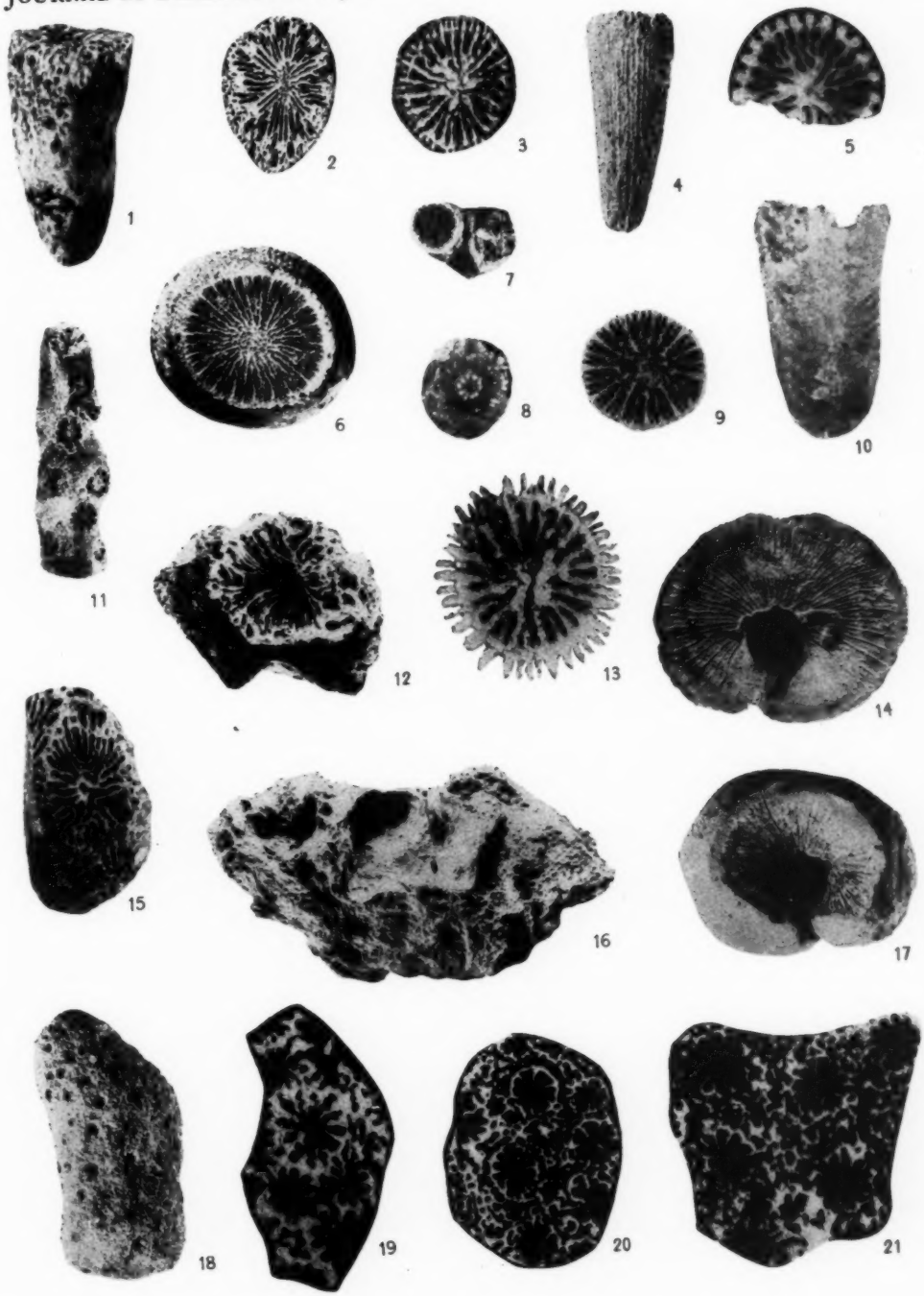
Occurrence: Loc. A-3206.

Geologic horizon: Crescent formation, middle Eocene.

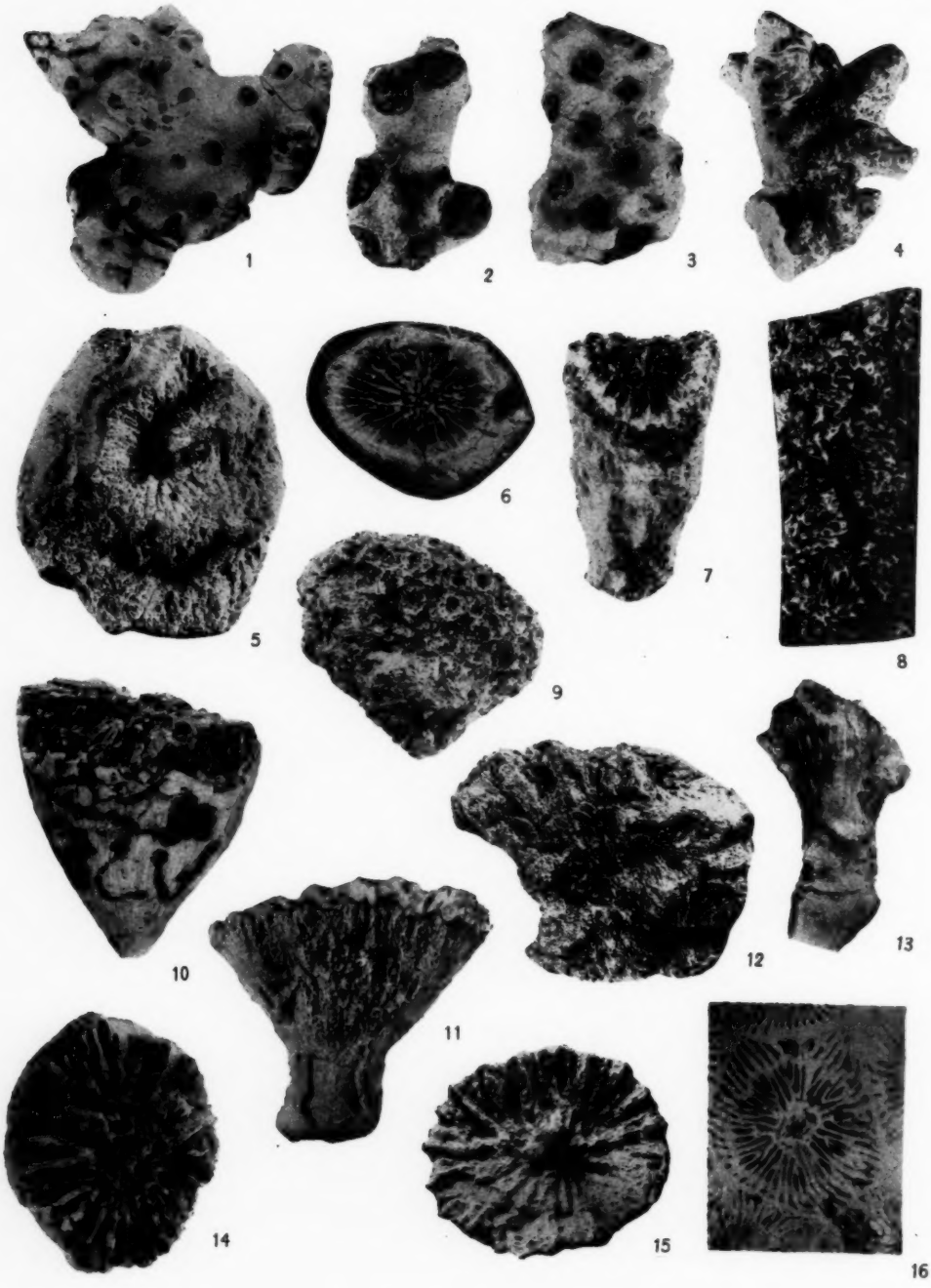
EXPLANATION OF PLATE 15

Unless otherwise stated, all specimen and locality numbers refer to the collections of the Museum of Paleontology, University of California at Berkeley.

FIG. *1*—*Balanophyllia fulleri* Durham, n. sp. Holotype, no. 12221, loc. A-1802, ×3.13. (p. 99)
2—*Balanophyllia washingtonensis* Durham, n. sp. Holotype, no. 12599, loc. A-3208; cross section near calyx, ×3.15. (p. 98)
3, 4, 13—*Turbinolia weaveri* Durham, n. sp. *3*, Paratype, no. 12564, loc. A-3207; cross section near calyx, ×6.42. *4*, Holotype, no. 12420, loc. A-3207; lateral view, ×3.55. *13*, Paratype, no. 12418, loc. A-3207; cross section midway of corallum, ×11.5, retouched. (p. 90)
5, 10—*Turbinolia quaylei* Durham, n. sp. *5*, Holotype, no. 14795, loc. A-3280; cross section near middle of corallum, ×13.6, retouched. *10*, Paratype, no. 14797, loc. A-3280; longitudinal section to show outline of corallum and alignment of septal granules, ×6.96. (p. 89)
6, 9—*Trochocyathus townsendensis* Durham, n. sp. *6*, Holotype, Leland Stanford, Jr., Univ. no. 6765, loc. N.P. 148; cross section near middle of corallum, ×1.81. *9*, Paratype, no. 12421, loc. A-1802; cross section of calyx just above top of columella, ×4.13. (p. 90)
7—*Astrangia clarki* Durham, n. sp. Paratype, no 12556, loc. A-1802; top of corallites. ×1.5. (p. 95)
8, 18—*Stylaster milleri* Durham, n. sp. *8*, Paratype, no. 12567, loc. A-1802; cross section of gastropore, showing pseudosepta, ×10.0. *18*, Paratype, no. 12412, loc. A-1802; massive form, ×3.70. (p. 102)
11—*Madracis stewarti* Durham, n. sp. Holotype, no. 14766, loc. A-3206, ×2.71; note spacing of calyces and prominent style. (p. 94)
12, 15—*Tubastrea nomlandi* Durham, n. sp. *12*, Paratype, no. 14761, loc. A-1802; cross section of calyx above columella, ×3.0. *15*, Holotype, no. 14762, loc. A-1802; cross section of a corallite with parts of adjacent individuals, ×4.2, retouched. (p. 101)
14, 17—*Flabellum hertleini* Durham, n. sp. Holotype, California Acad. Sci. no. 5978, loc. C.A.S. 912. *14*, Lateral view, ×0.55. *17*, Reverse view, ×0.51. (p. 92)
16, 21—*Montipora schencki* Durham, n. sp. Holotype, no 14781, loc. A-3206. *16*, Corallum, ×0.55. *21*, Etched cross section of calyces, × ±11.0, retouched. (p. 101)
19—*Astreopora duwamishensis* Durham, n. sp. Holotype, no. 12584, loc. A-3208; cross section, × ±10.0 retouched. (p. 101)
20—*Astreopora sanjuanensis* Durham, n. sp. Holotype, no. 12597, loc. A.-3206; cross section of calyces, × ±3.7, retouched. (p. 102)



Durham, Eocene and Oligocene Corals



Durham, Eocene and Oligocene Corals

Genus LEPTOPHYLLASTREA Oppenheim, 1930

Leptophyllastrea OPPENHEIM, *1930*, Anthozoen der Gosauschichten, p. 140.

Genolectotype: *Leptophyllastrea irregularis* Oppenheim, 1930 (Wells, 1936).

LEPTOPHYLLASTREA VAUGHANI
Durham, n. sp.
Plate 17, figures 3, 6

Corallum simple, large, subcylindrical at base and greatly flaring at top, diameter more than twice as great as height. Wall costate, fluted. Endotheca present. Costae averaging about one to a millimeter, interspaces nearly twice as wide as costae. New costae arise in interspaces as corallum increases in diameter. Calyces not very deep, eccentric, an irregular spongy columellar area projecting slightly. A minor secondary calycinal center near periphery. Septa of last cycle much thinner than those of preceding cycles, sometimes only about one-third as thick. Septal granules abundant. Sixteen septa of several cycles present at periphery of holotype in 10 mm. Septa of younger cycles often perforate.

Height of holotype and paratype, 25.0 mm. and ±24.0 mm.; top maximum diameter, 61.0 mm. and ±52.0 mm.; basal diameter, 25.0 mm. and ±35.0 mm.; depth of calyx, 5.0 mm. and ±5.0 mm.

Holotype, no. 14785; paratype, no. 14784.
Occurrence: Loc. A-3206.

Geologic horizon: Crescent formation, middle Eocene.

The presence of the minor secondary calycinal center distinguishes this genus from *Leptophyllia* Reuss (1854, p. 101).

SIDERASTREA de Blainville

Siderastrea DE BLAINVILLE, *1830*, Dict. des Sci. Nat., vol. 60, p. 335.
Siderastrea MILNE EDWARDS and HAIME, *1850*, Mon. Brit. Fossil Corals, p. 41.

Genotype: *Madrepora radians* Pallas.

SIDERASTREA WASHINGTONENSIS,
Durham, n. sp.
Plate 16, figure 16; plate 17, figure 19

Growth form explanate. Calyces large, irregularly polygonal and shallow. Septa in four cycles; the primaries and secondaries reach the columella, the tertiaries are fused to the secondaries close to the columella; the quaternaries are fused to the tertiaries at about two-thirds their length from the wall. Septa rather thick at their outer ends, becoming thinner towards the columella. Synapticulae usually in two rows near the outer edges of the septa, except where the calyx is an elongated area. The columella is rather large and projects up into the calyx, with the ends of the septa raised to meet it.

Long diameter of corallum of holotype,

EXPLANATION OF PLATE 16

Unless otherwise stated, all specimen and locality numbers refer to the collections of the Museum of Paleontology, University of California at Berkeley.

FIGS. *1–3*—*Archohelia weaveri* Durham, n. sp. *1*, Holotype, no. 12568, loc. A-1802; corallum, massive variety, ×0.59. *2*, Paratype, no. 12570, loc. A-1802; corallum, slender variety, ×2.0. *3*, Paratype, no. 12569, loc. A-1802; corallum, medium variety, ×1.08. (p. 93)
4—*Stylaster milleri* Durham, n. sp. Holotype, no. 12590, loc. A-1802, ×1.3. (p. 102)
5—*Colpophyllia reagani* Durham, n. sp. Holotype, no. 14779, loc. A-3206, ×1.02. (p. 96)
6, 7—*Caryophyllia woodmanensis* Durham, n. sp. *6*, Paratype, no. 14747, loc. A-3206; cross section near calyx, ×2.73. *7*, Holotype, no. 14748, loc. A-3206, ×2.69; corner broken from near side of calyx. (p. 91)
8—Eupsammid sp. Hypotype, no. 14788, loc. A-1801; polished section, ×2.07. (p. 101)
9—*Astreopora sanjuanensis* Durham, n. sp. Holotype, no. 12597, loc. A-3206; lateral view, ×1.56. (p. 102)
10, 14—*Caryophyllia wynoocheensis* Durham, n. sp. Holotype, no. 14783, loc. A-78. *10*, Lateral view, ×2.5; top of calyx broken. *14*, cross section, ×2.34. (p. 92)
11, 15—*Caryophyllia blakeleyensis* Durham, n. sp. Holotype, no. 14789, loc. A-1807. *11*, Lateral view, ×2.44. *15*, Calycular view, ×2.1. (p. 91)
12—Agaricid sp. Hypotype, no. 12543, loc. A-3206, ×1.04. (p. 98)
13—*Eusmilia bainbridgensis* Durham, n. sp. Holotype, no. 14792, loc. A-1807; lateral view, ×1.06. (p. 95)
16—*Siderastrea washingtonensis* Durham, n. sp. Holotype, no. 12588, loc. A-1807; polished section of a calyx, ×2.54; retouched. (p. 97)

55.0 mm.; short diameter of corallum, 45.0 mm.; thickness of corallum, 18.0 mm.; short diameter of calyx 1, 9.0 mm.; long diameter of calyx 1, 10.0 mm.; short diameter of calyx 2, 7.0 mm.; long diameter of calyx 2, 12.0 mm.

Holotype, no. 12588.

Occurrence: Loc. A-1807.

Geologic horizon: Lower Blakeley, upper Oligocene.

It differs from the type of *S. vancouverensis* Vaughan in that the calyces are larger, the septa are thicker, particularly near the wall, in proportion to their interspaces, and are also straighter, the synapticulae are usually in two or more rows, whereas according to Vaughan, the synapticulae of *S. vancouverensis* are in one or two rows.

SIDERASTREA VANCOUVERENSIS Vaughan

Siderastrea vancouverensis VAUGHAN, *1923*, California Univ., Dept. Geol. Sci., Bull., vol. 14, pp. 175–176, p. 40, figs. 1, 2.

Holotype, U. S. Nat. Mus.

Occurrence: I. E. Cornwall loc. C.

Geologic horizon: Sooke formation, upper Oligocene.

This species may be distinguished from *S. washingtonensis*, n. sp., by the means noted under that species.

The Sooke formation was correlated by Clark and Arnold with the Blakeley formation, but the exact equivalence of the formation is still open to doubt because of the general nonoccurrence of species of one fauna in the other.

A specimen of *Siderastrea* (hypotype, no. 12202) found at locality A–3447 (200 yards east of mouth of East Twin rivers in sea cliff, Clallam County, Washington, Upper Twin Rivers formation) was submitted to Dr. T. Wayland Vaughan at the United States National Museum for comparison with the type of *S. vancouverensis*. He reports,[8] that it is very similar to and probably should be identified with that species, though the specimen has somewhat larger calyces. This specimen has much deeper calyces than *S. washingtonensis*, n. sp. It measures 50 by 64 mm. Individual calyces are 10–11 mm. in diameter and up to 2.7 mm. deep.

[8] Personal communication, September 18, 1940.

SIDERASTREA? sp.
Plate 17, figure 21

A small specimen of a colonial coral with three calices referable to this genus was found at loc. A-1802, Quimper sandstone, lower Oligocene.

Hypotype, no. 12589.

AGARICID sp.
Plate 16, figure 12

A compound agaricid coral was found in the agglomerates at locality A-3206. It is not well enough preserved to be described, but has some characters suggesting *Coeloria* Milne Edwards and Haime.

Hypotype, no. 12543.

Geologic horizon: Crescent formation, middle Eocene.

Genus BALANOPHYLLIA Searles Wood, 1844

Balanophyllia SEARLES WOOD, *1844*, Annals and Mag. Nat. History, vol. 13, p. 11.

Genotype: *Balanophyllia calyculus* Searles Wood.

BALANOPHYLLIA WASHINGTONENSIS Durham, n. sp.
Plate 15, figure 2

Corallum subcylindrical, straight or slightly curved in the plane of the long diameter of the subcircular calyx. The character of the costae is poorly determinable because of the hardness of the matrix, but they appear to be broad with rather narrow interspaces, subrounded in profile. The wall is perforate.

The septa have the typical balanophylloid arrangement, with four complete cycles and part of the fifth present. Some septa considerably thickened, others not. Granules are not present near the top of the septa, but they appear irregularly farther down, sometimes opposite one another, at other times, one of the pair is absent.

The columella is of medium size, flattened in the plane of the long axis of the calyx, and is vesicular.

Dimensions of holotype and three paratypes

	Holotype mm.	Paratype mm.	Paratype mm.	Paratype mm.
Height			7	9
Long diam. calyx	5	3	3	4
Short diam. calyx	5	3	3	4
Diameter at base			3	3

Holotype, no. 12599; paratype, no. 12598.

Occurrence: Loc. A-3208.

Geologic horizon: Duwamish, upper Eocene.

B. washingtonensis n. sp. differs from *B. variabilis* Nomland (1916, p. 66, pl. 4, figs. 2–4, 13) from the Domengine sandstone in its much smaller size; in the septa being straighter, the wall more porous with less distinct costae. *B. variabilis* Nomland is also very elongate and cornute, whereas the present species is not so.

Balanophyllia fulleri
Durham, n. sp.
Plate 15, figure 1; plate 17, figure 4

Corallum subcylindrical, sometimes greatly curved in the plane of the long axis of the columella, at other times conical. Calyx nearly circular. Costae indistinct or none, surface usually reticulated. Often irregular bands of epitheca are present. The septa are in four cycles in the regular balanophylloid arrangement, and are all rather thin. Numerous granules are present, alternating on each side of a septum. The septa are slightly exsert, if at all, and are brought down in a rounded curve to form a narrow fossula, about 1.5 mm. deep.

The columella is compressed in the plane of curvature of the corallum, vesicular and rather thin.

Long diameter of calyx of the holotype, 6.3 mm.; short diameter of calyx, 5.1 mm.; diameter at base of corallum, 3 mm.; length of outside of curve of corallum, 11 mm.

Holotype, no. 12221; paratypes, nos. 12218–12220.

Occurrence: Loc. A-1802, very common, also occurs at locs. A-1808 and A-3213.

Geologic horizon: Quimper sandstone, lower Oligocene.

This species may be readily distinguished from *B. variabilis* Nomland by its smaller size, occasional bands of epitheca, abundant septal granules, and absence of costae; these last two characters serve to distinguish it from *B. washingtonensis*, n. sp., also.

Some of the specimens from loc. A-1808 reach a diameter of 8.5 mm., which is much larger than normal for this species.

Balanophyllia cf. *variabilis* Nomland cited by Effinger (1938, p. 388, pl. 47, fig. 20) from the type Gries Ranch fauna appears to be close to this species, but it cannot be definitely identified because the calyx is filled with secondary calcite. The costae on his specimen are locally prominent and granulose.

Balanophyllia teglandae
Durham, new name
Plate 17, figures 11, 13

"*Balanophyllia blakeleyensis* Quayle" in Teg-land, *1933*, California Univ., Dept. Geol. Sci., Bull., vol. 23, p. 142, pl. 15, fig. 11, 1933.

In the above cited reference, this species was merely listed as occurring in the Blakeley and credited to Quayle's manuscript, which has not been published to date. No description was given, and the figure is of the base of the corallum. Since no diagnosis was given, and the date of publication is subsequent to 1931, under Article 25c of the International Rules of Zoological Nomenclature, the species name is invalid.

Corallum apparently fairly large, with a prominent incrusting enlarged base. Costae well defined, rounded, slightly wider than their interspaces, with a single, irregular row of coarse granules. Costal interspaces with a single row of perforations. Septa in four cycles in a poorly defined balanophylloid pattern. Septal granules fairly abundant. Details of calyx lacking, as specimen is incomplete.

Diameter, 5.2 mm. where broken above base; height 5.5 mm., probably originally about 15.0 mm.

Holotype, no. 32245.

Occurrence: Given as loc. 681, but a slip with the specimen gives a locality description corresponding to loc. A-1807, which is more likely, as several coral species are known there.

Geologic horizon: ? Lower Blakeley formation, upper Oligocene.

This species may be distinguished from

other northern Balanophyllias by its prominent, well-defined costae.

Genus DENDROPHYLLIA de Blainville, 1830

Dendrophyllia DE BLAINVILLE, *1830*, Dict. des Sci. Nat., vol. 60, p. 319.

Genotype: *Madrepora ramea* Linnaeus

DENDROPHYLLIA HANNIBALI Nomland

Dendrophyllia hannibali NOMLAND, *1916*, California Univ., Dept. Geol. Sci., Bull., vol. 9, p. 67, pl. 6, figs. 1–3.

Holotype: Stanford Univ. Paleont. Coll.

Occurrence: Loc. N. P. 51 (not 15 as originally stated).

Geologic horizon: Equal to type Gries Ranch, lower Oligocene.

DENDROPHYLLIA COWLITZENSIS Durham, n. sp.

Plate 17, figures 22, 23

Corallum arborescent, corallites cylindrical to ovate and usually projecting. Main corallum walls perforate, very thick, but those of projecting individual corallites thin. Surface covered with close-set, narrow vermiculate costae. Individual corallites from 1.5 to 2.8 mm. in diameter, projecting from 0.5 to 2.0 mm. from surface of corallum. Calyces as much as 1.2 mm. deep. Septa not exsert, highly granulate, normal eupsammid pattern poorly developed. Individual septa sometimes irregularly thickened towards the center. Columella small, not projecting.

Holotype, no. 12600.

Occurrence: Loc. 7162.

EXPLANATION OF PLATE 17

Unless otherwise stated, all specimen and locality numbers refer to the collections in the Museum of Paleontology, University of California at Berkeley.

FIGS. *1, 10*—*Madracis crescentensis* Durham, n. sp. *1*, Holotype no. 14763, loc. A-3212, ×1.11; note close spacing of corallites. *10*, Paratype, no. 14764, loc. A-3212; cross section of calyces, ×±3.4. (p. 95)

2—*Colpophyllia reagani* Durham, n. sp. Paratype, no. 14778, loc. A-3206, ×0.33. (p. 96)

3, 6—*Leptophyllastrea vaughani* Durham, n. sp. *3*, Paratype, no. 14784, loc. 3206, viewed obliquely from below, ×0.65; note flaring top. *6*, Holotype, no. 14785, loc. A-3206; calycular view, ×0.58; note small secondary calycinal center in upper left. (p. 97)

4—*Balanophyllia fulleri* Durham, n. sp. Paratype, no. 12220, loc. A-1802; cross section of an incomplete specimen, ×5.9, retouched. (p. 99)

5—*Flabellum hertleini* Durham, n. sp. Paratype, no. 14791, loc. A-1810; incomplete cross section, ×1.36, to show angle of divergence of septa, outlined in black. (p. 92)

7—*Sclerhelia?* sp. Hypotype, no. 12562, loc. A-3211, ×0.77. (p. 94)

8—*Arcohelia weaveri* Durham, n. sp. Holotype, no. 12568, loc. A-1802; cross section of a corallite, ×5.7. (p. 93)

9—*Discotrochus* sp. Hypotype, no. 12250, loc. A-3207; basal view, ×7.9, retouched. (p. 92)

11, 13—*Balanophyllia teglandae* Durham, n. sp. Holotype, no. 32245, loc. 681. *11*, Lateral view, ×2.3, showing costae; calyx missing. *13*, Cross section ×3.0. (0. 99)

12—*Astrangia clarki* Durham, n. sp. Holotype, no. 12561, loc. A-1802, ×1.81; note costae. (p. 95)

14—*Coenocyathus? hannibali* Durham, n. sp. Holotype, Leland Stanford Junior Univ. no. 6767, loc. N.P. 207; cross section near calyx, ×4.22. (p. 93)

15, 18a, 18b—*Stephanocyathus holcombensis* Durham, n. sp. *15*, Holotype, no. 12500, loc. A-1810; basal view, ×1.06. *18a, 18b*—Paratype, no 12489, loc. A-1810; lateral views, ×1.31, of septa exposed on two sides of quarter segment of a corallum; in *18b*, pali from two different septa, outlined in black, are exposed. (p. 90)

16—*Paracyathus* sp. Hypotype, no. 12565, loc. A-1804; lateral view, ×3.1. (p. 92)

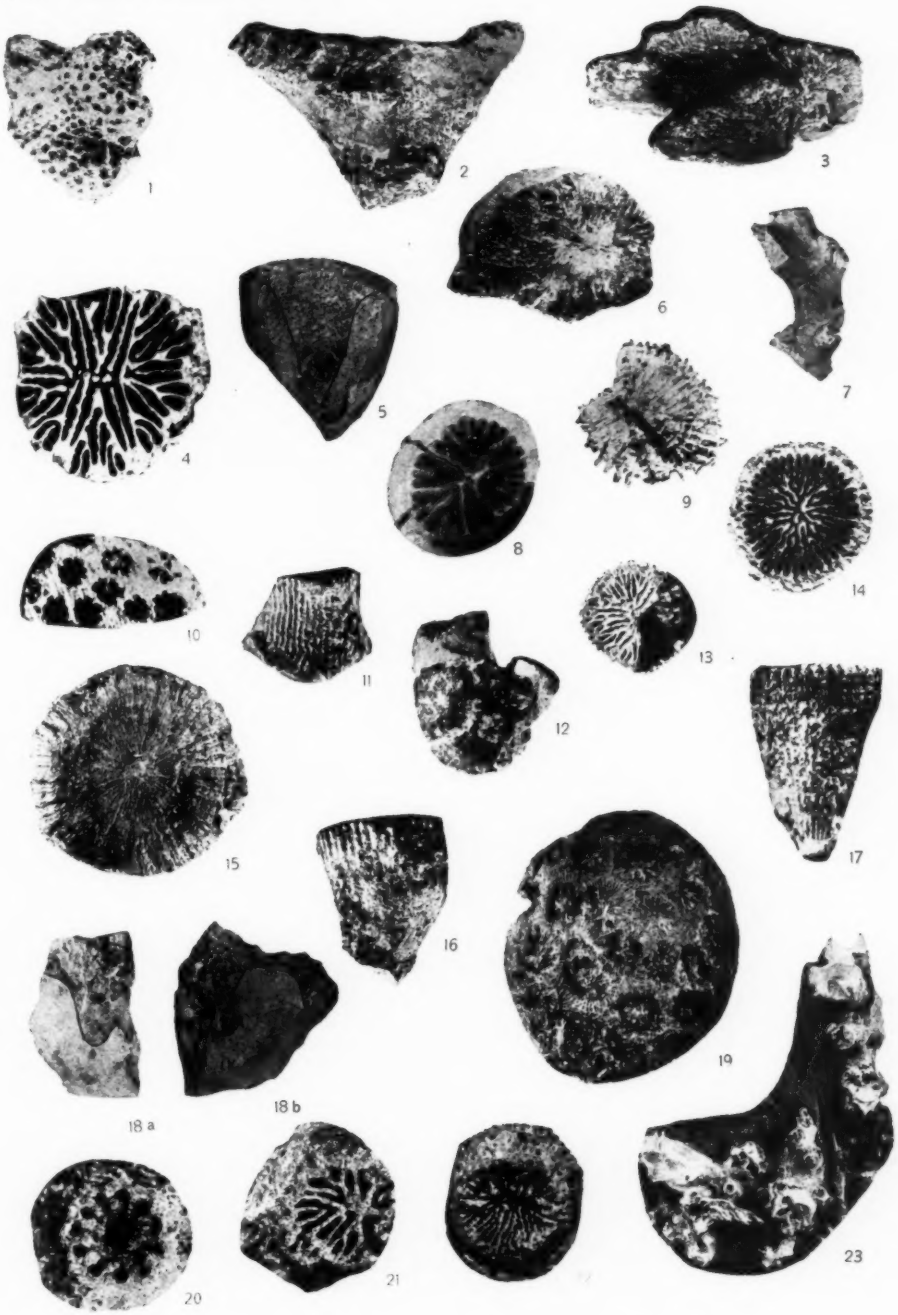
17—*Trochocyathus townsendensis* Durham, n. sp. Paratype, no. 12423, loc. A-1802, ×4.1; partly decorticated near base. (p. 90)

19—*Siderastrea washingtonensis* Durham, n. sp. Holotype, no. 12588, loc. A-1807, ×0.71. (p. 97)

20—*Stylaster milleri* Durham, n. sp. Holotype, no. 12590, loc. A-1802; a gastropore surrounded by dactylopores, ×±16.81; retouched. (p. 102)

21—*Siderastrea?* sp. Hypotype, no. 12589, loc. A-1802; calycular view, ×±5.0, retouched. (p. 98)

22, 23—*Dendrophyllia cowlitzensis* Durham, n. sp. Holotype, no. 12600, loc. 7162. *22*, A single calyx, ×5.35. *23*, Corallum, partly concealed in a calcareous nodule, ×0.62. (p. 100)



Durham, Eocene and Oligocene Corals

UNIV. OF MICH.

Geologic horizon: Cowlitz formation, upper Eocene.

This species may be distinguished from *D. hannibali* Nomland, *D. californica* Nomland, and *D. tejonensis* Nomland, by the much smaller corallites and less prominent columella.

Genus TUBASTREA Lesson, 1834

Tubastrea LESSON, *1834*, in BELANGER, Voy. Indes-Orient., p. 515.
Coenopsammia MILNE EDWARDS and HAIME, *1848*, Ann. Sci. Nat., ser. 3, t. 9, p. 106.

Genotype: *Tubastrea coccinea* Lesson, 1834, (*Lobophyllia aurea* Quoy et Gaimard 1833) (by monotypy).

TUBASTREA NOMLANDI
Durham, n. sp.
Plate 15, figures 12, 15

Corallum rather small, irregular, apparently encrusting. Calyces medium-sized, irregularly polygonal, adjacent and shallow. Septa in three complete cycles with a few of fourth present. The primaries fuse to form the irregular septal columella, the secondaries are largely fused to the primaries close to the columellar area, tertiaries usually fused to secondaries close to their junction with primaries, and the quaternaries, when present, may be fused to secondaries. Synapticulae usually in a single row near the periphery of the calyx. Only occasional granules present on the more or less crooked septa, which are from one-half to one-third the thickness of the interseptal loculi.

Length of holotype, 11.0 mm.; breadth, 5.0 mm.; one calyx 3.75 mm. by 5.0 mm.; another calyx about 7. 5 mm. by 4.0 mm.

Holotype, no. 14762; paratype, no. 14761.

Occurrence: Loc. A-1892.

Geologic horizon: Quimper sandstone, lower Oligocene.

EUPSAMMID sp.
Plate 16, figure 8

A specimen of a compound eupsammid coral was found at loc. A-1801; because of the hard calcareous matrix, it cannot be prepared sufficiently for description.

Hypotype, no. 14788.

Geologic horizon: Quimper sandstone, lower Oligocene.

Genus MONTIPORA Blainville, 1830

Montipora QUOY et GAIMARD, *1833*, Voyage de *l'Astrolabe*, Zooph., p. 247.

Genotype: *Montipora verrucosa* Quoy et Gaimard.

MONTIPORA SCHENCKI
Durham, n. sp.
Plate 15, figures 16, 21

Corallum lamelliform or massive, as much as 7 cm. or more thick and at least 18 cm. high. Calyces small, about 0.9 mm. in diameter, distant from one to one and one-half diameters from one another; depth uncertain, but apparently greater than diameter. Wall moderately distinct. Coenenchyma highly reticulate, extensive. Septa in two cycles, those of first cycle extending about two-thirds of distance to center, the second only about half as prominent. Sometimes a well-developed directive septa present. At depth, septa of first cycle sometimes appear to have coalesced to form a septal columella. No pali discernible.

Holotype, no. 14781.

Occurrence: Loc. A 3206.

Geologic horizon: Cresent formation, middle Eocene.

Occurs abundantly at the locality cited, scattered irregularly in black volcanic agglomerate.

Genus ASTREOPORA de Blainville, 1830

Astreopora DE BLAINVILLE, *1830*, Dict. des. Sci. Nat., vol. 60, p. 348.

Genotype: *Astrea myriopthalma* Lamarck

ASTREOPORA DUWAMISHENSIS
Durham, n. sp.
Plate 15, figure 19

Corallum forming very small, subglobular, attached masses, 1 cm. or less in diameter. The calyces are round or slightly irregular in shape, from 0.6 mm. to 1.1 mm. in diameter, and from 0.6 mm. to 1.0 mm. apart. The depth of the calyces varies from 0.4 mm. to 0.6 mm. The margins of the calyces are but very slightly elevated. The septa are in two cycles and are rather irregular in shape, but rather thick, sometimes thinning towards the center. As far as determinable, they are not exsert. Often a prominent, better developed directive septa is present. Columella absent.

The coenenchymal surface is apparently rather strongly perforate, but there may have been an impervious coat that was removed with the matrix.

Diameter of holotype, 15.0 mm.

Holotype, no. 12584; paratype, no. 12570.

Occurrence: Loc. no. A-3208, Seattle, Washington.

Geologic horizon: Duwamish, upper Eocene.

This species may be distinguished from *A. sanjuanensis*, n. sp., by the smaller calyces, thicker and more irregular septa.

ASTREOPORA SANJUANENSIS
Durham, n. sp.

Plate 15, figure 20; plate 16, figure 9

Corallum a moderately small, depressed spherical, attached mass. Calyces round, slightly raised, from 1.5 mm. to 2.0 mm. in diameter, distant from 0.5 to 2.0 mm. from one another. Coenenchyma loose, reticulated. Septa in two cycles, those of second cycle usually not complete. Those of first cycle lamellar, reaching nearly to center of calyx, thin and rather straight. Those of second cycle apparently more or less spiniform processes projecting from wall. Often an apparent directive septa present, sometimes shorter and heavier than the primaries and apparently belonging to the second cycle. No columella.

Height of holotype, 16.0 mm.; long diameter, 23.0 mm.; short diameter, 19.5 mm.

Holotype, no. 12597.

Occurrence: Loc. A-3206

Geologic horizon: Crescent formation, middle Eocene.

This species may be distinguished from *A. duwamishensis*, n. sp., by the larger calyces, the thinner and straighter septa.

Genus STYLASTER Gray, 1831

Stylaster GRAY, *1831*, Zool. Miscell., p. 36.

Genotype: *Madrepora rosea* Pallas

STYLASTER MILLERI Durham, n. sp.
Plate 15, figures 8, 18; plate 16, figure 4; plate 17, figure 20

Polyparia massive, irregular, with or without short, stubby, ill-defined branches. Gastropores generally distributed over the polyparia, from 0.5 mm. to 1.0 mm. apart and about 0.3 mm. in diameter. They are surrounded by a ring of 6 to 10 dactylopores, the ring being slightly raised. Style not quite flush with the surface and occupying from one-half to two-thirds of the calycular space. Ten to fourteen pseudosepta surround the style, apparently these pseudosepta are not always present. Dactylopores always regularly arranged around the gastropores and distant from it about their own diameter, which ranges from 0.1 mm. to 0. 2 mm. in large specimens. The dactylopores are occasionally provided with three or four septalike processes.

The polyparia is usually about 2 cm. in height, but may range up to 4 cm. or more.

Holotype, no. 12590; paratypes, nos. 12412, 12567.

Occurrence: Locs. A-1802, A-1808, and A-3209.

Geologic horizon: Quimper sandstone, lower Oligocene.

DESCRIPTION OF LOCALITIES

All localities, unless otherwise noted, are entered in the Register of Localities of the Museum of Paleontology, University of California at Berkeley.

681. Restoration Point, Bainbridge Island, Kitsap County, Washington. Type Blakeley formation, upper Oligocene.

7162. "Cowlitz lower shale near Vader, Washington, type locality." Possibly on Olequah Creek near town of Vader, but probably the famous locality at the bend of the Cowlitz river, 1½ miles east of Vader in NW ¼ SE ¼ sec. 27, T. 11 N., R. 2 W.

A-78. In gray shale outcrop on left bank of Wynooche river, 500 feet west and 400 feet south of NE cor. sec. 2, T. 19 N., R. 8 W., Grays Harbor County, Washington. Undifferentiated Oligocene.

A-1801. On beach just northeast of old alcohol plant, Port Hadlock, Washington, SE ¼ SW ¼ sec. 1, T. 29 N., R. 1 W. Quimper formation, lower Oligocene.

A-1802. Basal Quimper sandstone with congomerate lenses, resting on irregular surface of shale. In the sea cliff ¼ mile north of Woodmans Station (now known as Romona Beach), Discovery Bay, Jefferson County, Washington. SW ¼ NE ¼ sec. 8, T. 29 N., R. 1 W. Fauna equivalent to that of the Type Gries Ranch, lower Oligocene.

A-1804. In conglomerate bed at Middle Point, south side of Bremerton Inlet, sec. 9, T. 24 N., R. 2 E., Kitsap County, Washington. Blakeley formation, upper Oligocene.

A-1807. In lower Blakeley conglomerate at Beans Point, Bainbridge Island, Kitsap County, Washington (equivalent to Univ. Washington

loc. 305). Blakeley formation, upper Oligocene.

A-1808. Basal Quimper sandstone resting on Eocene basalts. Exposed on beach about 1 mile north of Mat-Mats Bay, Quimper Peninsula, Jefferson County, Washington, sec. 29, T. 29 N., R. 1 E. Fauna equivalent to that of A-1802, lower Oligocene.

A-1810. Glauconitic shale exposed in bluff on north side of bend of the Willapa river about ¼ mile east of Holcomb, Pacific County, Washington. Fauna equivalent to that of Keasey Formation of Oregon. Lower Oligocene.

A-1812. Conglomerate and shale beds on small peninsula in NW ¼ SW ¼ of sec. 8, T. 24 N., R. 2 E., Kitsap County, Washington. Blakeley formation, upper Oligocene.

A-3206. Fossiliferous tuffaceous agglomeratic beds 330 yards southwest of sea stack along beach at Observatory Point, Clallam County, Washington, sec. 25, T. 31 N., R. 8 W. Crescent formation, middle Eocene.

A-3207. In a thin bed of very fossiliferous shaly sandstone on highway, ¾ of a mile east of A-3208. "Duwamish Eocene," King County, Washington.

A-3208. In sandstone exposed on the northwest end of low hill parallel to the Duwamish river. North side of sec. 10, T. 23 N., R. 4 E. "Duwamish Eocene," King County, Washington.

A-3209. Basal Quimper sandstone resting on basalt, on the southeast corner of the rocky island in Port Hadlock Bay, Jefferson County, Washington, sec. 1, T. 29 N., R. 1 W. Fauna equivalent to that of A-1802, lower Oligocene.

A-3210. In shale, just east of minor anticline, south side of Richs Passage, NE ¼ NW ¼ sec. 9, T. 24 N., R. 2 E., Kitsap County, Washington. Blakeley formation, upper Oligocene.

A-3211. In shale with conglomerate lenses, about 200 feet northwest of A-1807, Beans Point, Bainbridge Island, Kitsap County, Washington. Blakeley formation, upper Oligocene.

A-3212. In black tuffaceous sandstone below basaltic agglomerates, on west side of west point of Port Crescent, Clallam County, Washington. Center of sec. 20, T. 31 N., R. 8 W. Crescent formation, middle Eocene.

A-3213. In a blue-grey sandstone with abundant fragments of tuff, resting on basalt, at the junction of Fir and Vance Creeks, at mouth of old prospect tunnel. On section line between secs. 3 and 10, T. 21 N., R. 5 W., Mason County, Washington. Lower Oligocene.

A-3280. A calcareous concretion in black shales of Crescent formation. Road cut, 0.9 miles east from Elwha river bridge, Port Angeles-Lake Crescent highway, Clallam County, Washington.

C. A. S. loc. 912. On Willapa river near Holcomb, Washington. (Same locality as A-1810.)

I. E. Cornwall locality C. About one-half mile up Kirby Creek from its mouth, on the east side of the creek, Vancouver Island. Sooke Formation, British Columbia.

N. P. 148. "Lower Astoria, basal tuffaceous sandstone, seacliffs ¼ mi. north of old Woodman Wharf, Port Discovery, Washington." Jefferson County, Washington, NE ¼ sec. 8, T. 29 N., R. 1 W. Quimper formation, lower Oligocene. (Same locality as A-1802.)

N. P. 51. At old log dam on Porter Creek a little over 1½ miles up Porter Creek from the town of Porter. Basal Oligocene, unconformable on Eocene basalts. Grays Harbor County, Wash., sec. 14, T. 17 N., R. 5 W.

N. P. 167. "Lower Astoria conglomerate seacliffs at Koitlah Point, west of Neah Bay." Clallam County, Washington, SE ¼ sec. 4, T. 33 N., R. 15 W. Lower or middle Oligocene.

N. P. 207. "Lower Astoria tuffaceous shale bluffs on Vance's Creek 2½ miles above junction with Skokomish River, 13 miles above Union City." Mason County, Washington, T. 21 N., R. 5 W.

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SOME CLAIBORNE EOCENE OSTRACODA OF THE GENUS CYTHERIDEA FROM THE GULF COAST

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ABSTRACT—Eleven species, seven of which are new, and one new variety, of the ostracode genus *Cytheridea*, are described and figured. The species were collected from material of the Claiborne Eocene at outcrops in the states of Alabama, Louisiana, Texas, and in the state of Vera Cruz, Mexico.

IN THE FALL of 1936, I visited the classic exposure of Claiborne Eocene sediments at Claiborne Bluff on Alabama River, Alabama, in company with members of the staff of the School of Geology at Louisiana State University. Collections made at that time have formed the basis for my study of the Claiborne Ostracoda in that state. A wealth of material from hundreds of Claiborne outcrop localities in northern Louisiana has been made available to me through recent studies of the Louisiana Geological Survey in Winn and Natchitoches Parishes. Only a few of the many Louisiana stations studied are included as localities in the present report, representing those which carry the most prolific and varied faunas from the several Claiborne formations. The study has been extended into the Claiborne of Texas by including several localities from the Weches and Cook Mountain formations. A single station from Mexico, correlated with the Tempoal formation by Muir (1936), completes the geographic distribution of species identified.

Rather exhaustive studies of both the Foraminifera and Ostracoda of the Claiborne group of Louisiana have been in progress at Louisiana State University. A report of Claiborne species of the Ostracode genus *Loxoconcha* by Murray (1938), was the first of these studies to appear in published form. Martin (1939) later published on the genus *Cytheropteron*, and Gooch (1939) on some species of *Cythereis*. The Cook Mountain Foraminifera have been recently described by Howe (1939), in a bulletin of the Louisiana Geological Survey. An earlier paper by Cushman (1925) recorded both Ostracoda and Foraminifera from Eocene strata exposed on Moctezuma River in Mexico, a locality included in the present report. Stadnichenko (1927) also described both Ostracoda and Foraminifera from the Cook Mountain of Lee County, Texas. A study of Weches Ostracoda from Smithville, Bastrop County, Texas, by Sutton and Williams (1939), was one of the more recent additions to the literature.

A detailed stratigraphic study of the Claiborne lies outside the scope of the present report. It is hoped that the species of *Cytheridea* here described will aid in the closer correlation of Claiborne sediments in the Gulf Coast. Two of the species herein included, *Cytheridea* (*Haplocytheridea*) *montgomeryensis* Howe and Chambers, and *Cytheridea* (*Clithrocytheridea*) *garretti* Howe and Chambers, previously described from the Jackson group, are here recorded from the underlying Claiborne. The remainder of the species are confined in my collections to sediments within the Claiborne group.

No long distance correlation of sediments across the Gulf Coast seems advisable with the material at hand. The highly fossiliferous Lisbon formation of Alabama carried the most abundant and varied fauna within the genus *Cytheridea* of any of the formations studied and contained five species which were not identified from the overlying Gosport. The Cook Mountain formation of Louisiana, though highly fossiliferous at some stations, carried fewer species than the Alabama section. The underlying Cane River formation appears readily distinguishable from it, with only two species common to both formations. The Cook Mountain and Weches formations of Texas are rather difficultly separable on the basis of the genus *Cytheridea*. The Tempoal of Mexico was easily identified through the

rather abundant occurrence of *Cytheridea* (*Haplocytheridea*) *mexicana* Stephenson, n. sp. Lack of material from the Mexican Claiborne precludes the possibility of establishing the range of this species.

The samples of fossiliferous material upon which this report is based have been acquired through the cooperation of a number of geologists and paleontologists. I am deeply grateful to Dr. Henry V. Howe, of Louisiana State University, for placing at my disposal the facilities and microfossil collections of the Louisiana Geological Survey. Slides of Claiborne Ostracoda from the personal collection of Doctor Howe, as well as those from the collections of advanced graduate students at the University proved very helpful. I am indebted to Dr. John Huner and to Dr. Justin Rukas, who collected most of the Louisiana Claiborne outcrop samples studied. My thanks are extended to Mr. J. B. Garrett and Mr. A. D. Ellis, Jr., Stanolind Oil and Gas Company, Houston, Texas, and Mr. R. W. Barker, all of whom supplied outcrop material. Dr. J. H. McGuirt, Dr. Keith Hussey, and Mr. D. D. Gooch rendered valuable assistance.

The type specimens upon which this report is based have been deposited in the Henry V. Howe collection, Louisiana State University, University, Louisiana. The localities from which specimens were collected are described at the end of the paper.

Systematic Descriptions

Family Cytheridae Baird, 1850

Genus Cytheridea Bosquet, 1852

Subgenus Haplocytheridea Stephenson, 1936

Cytheridea (Haplocytheridea) goochi Stephenson, n. sp.

Plate 18, figures 9, 10

Carapace small, tumid, moderately heavy; in side view elongate, subovate, highest somewhat anterior to the middle. Dorsal margin moderately well arched, sloping fairly strongly toward the posterior in the right valve, descending weakly in the left valve. Ventral margin somewhat convex or faintly sinuated. Anterior end broadly and obliquely rounded, more broadly rounded in the larger left valve. Posterior end nearly as broad as the anterior in the left valve; in the right valve sloping gently to the narrow, roundly pointed posteroventral angle. Tumid portion of the surface is fairly closely covered with rather deep pits of moderate size, the pitting being less pronounced toward the periphery and leaving the peripheral area smooth. Hinge in the right valve consists of slightly elevated, weakly notched dental areas, between which is a low line of faint crenulations. Hinge in the left valve is composed of weakly incised, notched sockets, the anterior much the longer and more prominent. Between the sockets and continuous with them is a shallow, finely notched furrow, terminated dorsally by the rounded dorsal margin. Marginal areas fairly broad on the anterior, rather narrow on the posterior. Line of concrescence coincides with the inner margin except on the anterior and posterior, where it extends somewhat into the marginal area.

Length (male) 0.54 mm; height 0.30 mm.; width 0.27 mm. Length (female) 0.52 mm.; height 0.31 mm.; width 0.28 mm.

Remarks.—The new species is close to *C.* (*H.*) *hadleyi* Stephenson (1937, pp. 150, 151, pl. 26, fig. 16), from the basal portion of the Jackson Eocene of Mississippi. *C.* (*H.*) *goochi* is a much smaller form in the adult, and is shorter in comparison to its height, a feature especially noticeable in the right valve. The Claiborne species is normally more strongly pitted, with the pits somewhat more closely spaced. This species is much more strongly pitted than *C.* (*H.*) *husseyi* Stephenson, n. sp., with which it is associated at the type locality, and is more angular in side view.

Sexual dimorphism is noticeable in this species, with the female more tumid, more rounded in outline in side view, and less elongate than the male.

Named in honor of D. D. Gooch, former Assistant State Geologist of Louisiana, whose suggestions and loan of material have aided in the present study.

Occurrence.—In my collections, the species is confined to the Claiborne of Alabama. It occurs commonly in the Gosport and rarely in the Lisbon at Loc. 1. Figured specimens were obtained from Loc. 1 c.

Types.—Holotype (complete specimen, female), H. V. Howe coll., no. 1574; paratypes, nos. 1575–1577.

CYTHERIDEA (HAPLOCYTHERIDEA) HABROPAPILLOSA Sutton and Williams
Plate 18, figures 21, 22

Cytheridea mülleri (Münster) (part). STADNICHENKO, *1927*, Jour. Paleontology, vol. 1, pp. 238, 239, pl. 39, figs. 14–17 (not fig. 13).
Cytheridea (*Haplocytheridea*) *habropapillosa* SUTTON and WILLIAMS, *1939*, Jour. Paleontology, vol. 13, pp. 570, 571, pl. 64, figs. 20–22.

This species was originally figured as *Cytheridea mülleri* (Münster) by Stadnichenko (1927), a fact which Sutton and Williams (1939) failed to note in describing the form as new. It is one of the most distinctive species present in the microfauna of the Claiborne group. It may easily be confused, however, with *C.* (*H.*) *wallacei* Howe and Garrett (1934, pp. 44, 45, pl. 3, figs. 5–8) from the underlying Wilcox Eocene. The Claiborne species is more acute and more compressed on the posterior, with the ventral margin incurved in its posterior half, and the posteroventral angle produced ventrally. A comparison of specimens of the new species with topotypes of *C.* (*H.*) *wallacei* from Sabinetown, Texas, indicates the Claiborne species to be papillose over a more limited area on the most inflated portion only. Specimens referred by me (Stephenson, 1938, p. 575, pl. 67, fig. 25) to *C.* (*H.*) *wallacei* from the Wilcox of Alabama, however, show even fewer papillae than are exhibited by *C.* (*H.*) *habropapillosa*.

Material studied from the type locality of the Cane River formation of the Claiborne of Louisana, near Natchitoches, Natchitoches Parish, indicates a somewhat dwarfed form of the species to occur in this area (pl. 18, fig. 21). Specimens from this locality also show a broad, vertically depressed area anterior to the middle, with a strongly inflated region posterior to it, and somewhat ventral to the center of the carapace. All specimens from this locality show these distinctive features, which I have noted in no other Claiborne ostracode faunas. The variation seems, however, scarcely worthy of varietal distinction and has been included with the typical form.

Length (including spines) 0.74 mm.; height 0.43 mm.; width 0.41 mm.

Occurrence.—The species has been reported from the Cook Mountain of Texas by Stadnichenko (1927, pp. 238, 239). It was erroneously referred to *Cytheridea mülleri* (Münster) in this report. At least one other species (see Stadnichenko, 1927, pl. 39, fig. 13) was included with *C.* (*H.*) *habropapillosa*, an error noted by Alexander (1934, p. 225), and later by me (Stephenson, 1936, p. 698).

In my collections, the species occurs rarely in the Lisbon of Alabama at Loc. 1, but I have no specimens from the Gosport at this station. I have not identified it from the Cook Mountain of Louisiana, but have found it to occur in the Cane River at Locs. 9, 10, 13, and 14. In Texas it is common in the Cook Mountain at Evergreen and Orell's Crossings, and rare in the Weches formation. The figured specimens are all from the material from Loc. 15, except for hypotype 1573, which is from Loc. 9.

Types.—Hypotypes, H. V. Howe coll., nos. 1568–1573.

CYTHERIDEA (HAPLOCYTHERIDEA) HUSSEYI Stephenson, n. sp.
Plate 18, figure 3

Carapace small, tumid; in side view subovate, thickest toward the posterior. Dorsal margin very weakly arched, convex between the obscure cardinal angles, and joining in an even curve the broadly rounded anterior end and the equally well rounded posterior end. Ventral margin straight to somewhat sinuated in the right valve, slightly convex in the left valve. Left valve larger than the right and tending to be considerably more inflated on the posterior. Surface smooth, showing a limited number of small, rather obscure pits. Hinge in the right valve composed of narrow, slightly raised dental areas, notched to form about six cusps, and joined by a line of low crenulations. In the left valve, hinge with elongate, notched sockets, between which is a faintly crenulate trench, outlined dorsally by the fairly prominent rounded bar of the dorsal margin. Marginal area moderately broad on the anterior, narrow on the posterior. About 20 straight, simple, radial pore canals are visible on the anterior. Line of concrescence coincides with the inner margin except on anterior and posterior, where it falls somewhat within the marginal area.

Length 0.53 mm.; height 0.32 mm.; width 0.31 mm.

Remarks.—*C.* (*H.*) *husseyi* may easily be confused with *C.* (*H.*) *chambersi* Stephenson (1937, pp. 147, 148, pl. 26, fig. 2), a species from the overlying basal portion of the Jackson Eocene. The Claiborne species is much smaller, and is more weakly arched at the anterodorsal angle, giving the carapace a more ovate outline in side view. Free right valves of the new species are well rounded on the posterior, whereas the right valve of the Jackson form is narrow to the roundly pointed posteroventral angle, which is usually slightly produced ventrally.

The species is named in honor of Keith Hussey, of the University of Houston, Houston, Texas, for his work on the Foraminifera of the Claiborne of Louisiana.

Occurrence.—The species is rare in the Lisbon of Alabama. It is described from Loc. 1 d. In the Cook Mountain of Louisiana, it is common at Loc. 4, rare at Locs. 6 and 7.

Types.—Holotype (complete specimen), H. V. Howe coll., no. 1578; paratypes, no. 1579, 1580.

CYTHERIDEA (HAPLOCYTHERIDEA) LISBONENSIS Stephenson, n. sp.
Plate 18, figures 11, 12

Cytheridea mülleri CUSHMAN, *1925*, Am. Assoc. Petroleum Geologists Bull., vol. 9, pp. 301, 302, pl. 8, figs. 4, 5.

Carapace tumid; in side view subpyriform, highest at about the anterior one-third the shell length. Dorsal margin moderately well arched, flattened along the hinge line, and sloping gently toward the posterior; ventral margin convex. Anterior end broadly and evenly rounded, often bearing about six very short, blunt, inconspicuous spines; posterior end narrower but well rounded, at times spinose like the anterior. Surface rather strongly sculptured, most specimens showing a broad, shallow, median, vertically elongated depressed area. Tumid portions of the surface exhibit a series of vertical, curvilinear furrows, nearly straight at the center of the carapace, and becoming more strongly arcuate toward anterior and pos-

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EXPLANATION OF PLATE 18

All figures approximately ×53

FIGS. *1*—*Cytheridea* (*Clithrocytheridea*) *garretti* Howe and Chambers. Right valve view of a female. Lisbon, Claiborne Bluff, Ala. (p. 110)

2—*Cytheridea* (*Clithrocytheridea*) *smithvillensis* Stephenson, n. sp. Right valve view. Lisbon, Claiborne Bluff, Ala. (p. 113)

3—*Cytheridea* (*Haplocytheridea*) *husseyi* Stephenson, n. sp. Right valve view. Lisbon, Claiborne Bluff, Ala. (p. 107)

4—*Cytheridea* (*Haplocytheridea?*) sp. Right valve view. Lisbon, Claiborne Bluff, Ala. (p. 110)

5, 6—*Cytheridea* (*Clithrocytheridea*) *gosportensis* Stephenson, n. sp. Right and left valves. Gosport, Claiborne Bluff, Ala. (p. 111)

7, 8—*Cytheridea* (*Haplocytheridea?*) sp. Right and left valves. Cook Mountain, Orell's Crossing, Tex. (p. 110)

9, 10—*Cytheridea* (*Haplocytheridea*) *goochi* Stephenson, n. sp. *9*, Right valve view of a male. *10*, Right valve view of a female. Lisbon, Claiborne Bluff, Ala. (p. 106)

11, 12—*Cytheridea* (*Haplocytheridea*) *lisbonensis* Stephenson, n. sp. *11*, Right valve view of complete specimen from the Lisbon, Claiborne Bluff, Ala. *12*, A left valve from the Cook Mountain, Evergreen Crossing, Lee Co., Tex. (p. 108)

13—*Cytheridea* (*Haplocytheridea*) *mexicana* Stephenson, n. sp. Right valve view. Tempoal, Moctezuma River, Vera Cruz, Mexico. (p. 109)

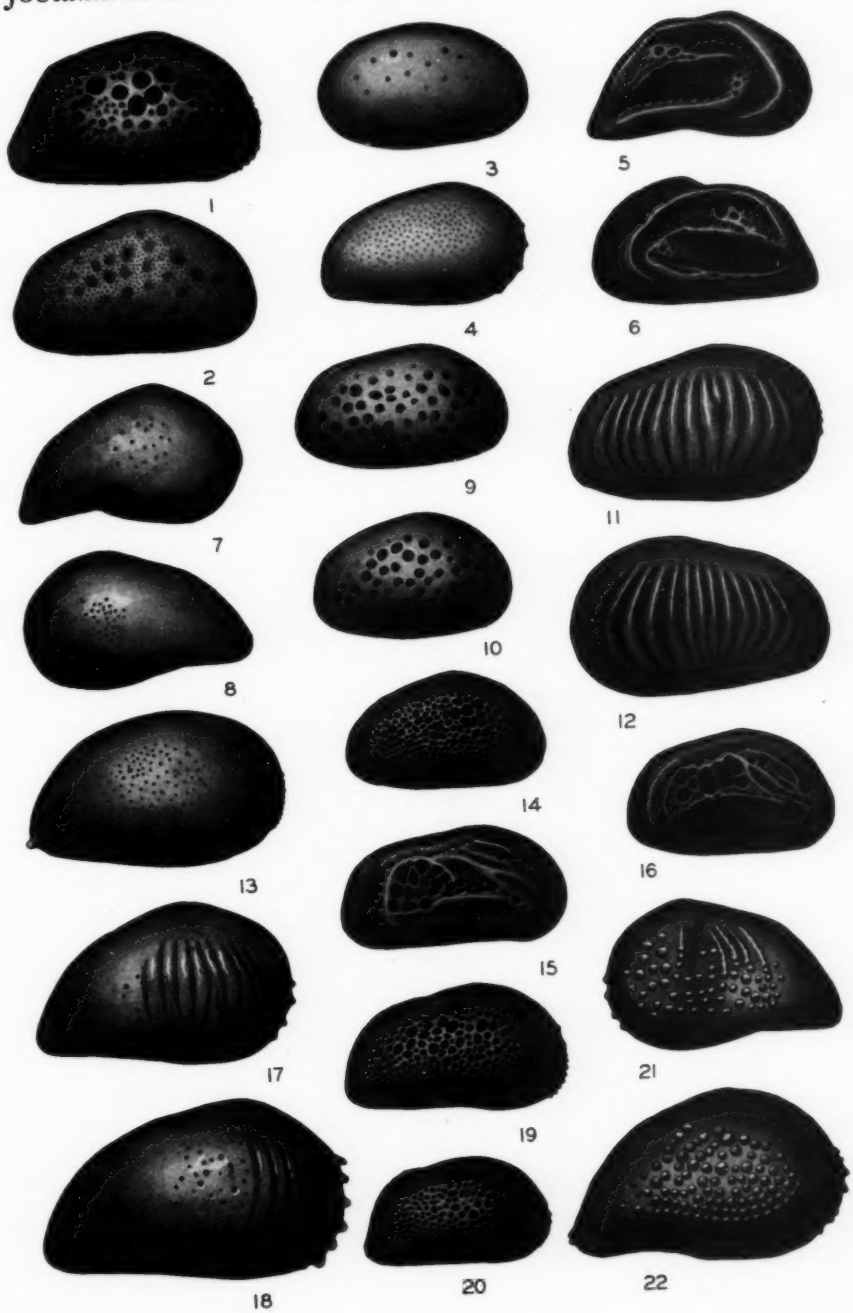
14—*Cytheridea* (*Clithrocytheridea*) *subpyriformis* Sutton and Williams, var. *wechesensis* Stephenson, n. var. Right valve view of a female. Weches, Smithville, Tex. (p. 113)

15, 16—*Cytheridea* (*Clithrocytheridea*) *semireticulata* Stephenson, n. sp. *15*, Right valve view of a male. *16*, Right valve view of a female. Lisbon, Claiborne Bluff, Ala. (p. 112)

17, 18—*Cytheridea* (*Haplocytheridea*) *montgomeryensis* Howe and Chambers. *17*, Right valve view of a female. *18*, Right valve view of a male. Lisbon, Claiborne Bluff, Ala. (p. 109)

19, 20—*Cytheridea* (*Clithrocytheridea*) *oliveri* (Cushman). *19*, Right valve view of a complete specimen from the Cook Mountain, Winn Parish, La. *20*, Right valve view of a specimen from the Tempoal, Moctezuma River, Vera Cruz, Mexico. (p. 111)

21, 22—*Cytheridea* (*Haplocytheridea*) *habropapillosa* Sutton and Williams. *21*, A left valve from the Cane River, Natchitoches, La. *22*, Right valve view of a specimen from the Cook Mountain, Evergreen Crossing, Tex. (p. 107)



Stephenson, Claiborne Eocene Ostracoda

UNIV. OF MICH.

terior peripheries. Each furrow carries rather closely spaced, deep pits of moderate size. A series of rounded ridges separates the furrows. Ornamentation becomes obscure toward the periphery, which is nearly smooth. Interior of valves deep and smooth. Hinge structure in the right valve consists of two low, very faintly notched dental areas, between which is a slightly lower line of fine crenulations, separated from the dorsal margin by a faintly incised line. In the left valve, hinge with notched terminal sockets, immediately behind the anterior of which is a shallow, faintly notched groove, which becomes deeper as it approaches and finally merges with the posterior socket. The low dorsal margin extends as a narrow bar above the connecting groove. Marginal areas fairly broad, bearing about 25 simple radial pore canals on the anterior, with a fewer number on the posterior. Line of concrescence coincides with the inner margin except on anterior and posterior, where it extends slightly within the marginal area.

Length 0.66 mm.; height 0.39 mm.; width 0.33 mm.

Remarks.—This species bears some resemblance to *C.* (*Cytheridea*) *mülleri* (Münster), the Oligocene species from Germany designated as genotype for this genus. This similarity led Cushman (1925) to refer specimens from his Moctezuma River locality in Mexico to the European species. The genotype is, however, much larger, and, though it is fairly strongly pitted, there is no evidence of the curvilinear furrows characterizing the new species. The hinge of the genotype (see Stephenson, 1936, pl. 94, figs. 1, 2) is also much more complex. The new species is more heavily ornamented, smaller, and less tumid than *C.* (*H.*) *bastropensis* Sutton and Williams in the Weches formation of Texas.

Occurrence.—The species is fairly common in the Lisbon of Alabama, from which it is described. Though apparently absent from the Cook Mountain of Louisiana, it occurs very rarely in the Cane River at Locs. 11 and 14. It is rather common in the Cook Mountain and Weches formations of Texas, and I have one specimen from the Claiborne of Mexico, at Loc. 19.

Types.—Holotype (complete specimen), H. V. Howe coll., no. 1581; paratypes, nos. 1582–1584. Paratype 1584 is from Loc. 15; all specimens other than this from Loc. 1 d.

CYTHERIDEA (HAPLOCYTHERIDEA) MEXICANA Stephenson, n. sp.
Plate 18, figure 13

Carapace tumid, fairly large; in side view subpyriform, highest somewhat anterior to the middle. Left valve larger than the right, overlapping around the entire periphery, with the greatest overlap along the ventral margin. Dorsal margin gently arched; ventral margin convex, more strongly so on the left valve. Anterior end broadly and evenly rounded, bearing about ten very short, blunt, inconspicuous spines on the ventral half. Posterior end slopes gently from the obscure posterocardinal angle to the narrowly rounded posteroventral angle, which often bears one or more short, blunt spines. General surface smooth, the most inflated portion of the carapace wall showing a shallow, fairly closely spaced pitting. Hinge in the right valve consists of notched, terminal dental areas, between which is a low line of crenulations, separated from the dorsal margin by a well-incised line. In the left valve, hinge with elongate, notched sockets, with a crenulate furrow between and continuous with them. Marginal areas fairly broad, bearing about 20 radial pore canals on the anterior, with a fewer number on the posterior and along the entire ventral margin.

Length 0.79 mm.; height 0.39 mm.; width 0.35 mm.

Occurrence.—I have noted this species only in the Claiborne of Mexico, where it occurs at Loc. 19. Specimens from the type locality are completely filled with calcite.

Types.—Holotype (complete specimen), H. V. Howe coll., no 1585.

CYTHERIDEA (HAPLOCYTHERIDEA) MONTGOMERYENSIS Howe and Chambers
Plate 18, figures 17, 18

Cytheridea montgomeryensis HOWE and CHAMBERS, *1935*, Louisiana Dept. Cons. Geol. Bull. 5, pp. 17, 18, pl. 1, fig. 1; pl. 2, figs. 1–3, 7, 9; pl. 6, figs. 17, 18.

Cytheridea (*Haplocytheridea*) *montgomeryensis* STEPHENSON, *1936*, Jour. Paleontology, vol. 10, pp. 700, 701, pl. 94, figs. 3, 4, 9; text figs. 1 g, h, j, k.

Cytheridea (*Haplocitheridea*) *montgomeryensis* STEPHENSON, *1937*, idem, vol. 11, p. 153.

In the extensive collections from the Clai-

borne group available for study, this species has been present in nearly every sample. It is usually quite common in upper Claiborne material, and often forms a substantial portion of the ostracode fauna. Claiborne specimens appear to be identical in every respect to those from the type locality of the species in the basal Jackson at Montgomery, Louisiana.

Range.—*C.* (*H.*) *montgomeryensis* was originally reported by Howe and Chambers (1935, p. 3) from the middle and lower Jackson of Louisiana. I later noted (Stephenson, 1937, p. 153) that, although the species had not been identified from any upper Jackson station carrying *Massilina pratti*, it was nevertheless present in a sample from Mississippi, in Jackson beds immediately underlying the Red Bluff Oligocene. The range of the species is thus apparently from the Cook Mountain Claiborne through the Jackson Eocene.

Length (male) 0.80 mm.; height 0.41 mm.; width 0.36 mm.; length (female) 0.68 mm.; height 0.44 mm.; width 0.35 mm.

Types.—Hypotypes, H. V. Howe coll., nos. 1586–1589, from Loc. 1 c.

CYTHERIDEA (HAPLOCYTHERIDEA?) sp.
Plate 18, figure 4

Occasional thin, fragile specimens such as the one figured were encountered in the material examined. The shell characters of these carapaces suggests the strong probability that they are young specimens, or perhaps the young moults of another species. Such specimens as these were formerly classed under "*Leptocytheridea*," a subgenus which I now consider invalid. The hinge structure, which is weakly developed, is not typical for either *Haplocytheridea* or *Clithrocytheridea*. In the right valve, the hinge is composed of slender, slightly elevated, faintly notched dental areas. A faintly incised groove behind the anterior dentition is replaced by a low bar about the midpoint of the hinge, which rises to join the posterior dental area. In the left valve, hinge with narrow, notched sockets. A slender, rounded bar, most prominent behind the anterior socket, gives way to a faintly visible groove near the posterior socket. A well-incised line separates the bar from the dorsal margin.

Length of figured specimen 0.52 mm.; height 0.31 mm.; width 0.24 mm.

Figured specimen.—H. V. Howe coll., no. 2285; other specimens, nos. 2286, 2287. All specimens from Loc. 1 d.

CYTHERIDEA (HAPLOCYTHERIDEA?) sp.
Plate 18, figures 7, 8

Rare specimens such as those illustrated occur in my collections from the Claiborne group. They are closely similar to the form described by Howe and Garrett (1934, pp. 31, 32, pl. 1, figs. 16–18) as *Cytheridea hopkinsi*. Like the form described immediately above, these are probably young specimens.

Length (right valve) 0.57 mm.; height 0.35 mm.; length (left valve) 0.58 mm.; height 0.34 mm.

Figured specimens.—H. V. Howe coll., nos. 1599, 1600, from Orell's Crossing, Texas.

Subgenus CLITHROCYTHERIDEA Stephenson, 1936

CYTHERIDEA (CLITHROCYTHERIDEA) GARRETTI Howe and Chambers
Plate 18, figure 1

Cytheridea? garretti HOWE and CHAMBERS, *1935*, Louisiana Dept. Cons. Geol. Bull. 5, p. 14, pl. 1, figs. 4, 5; pl. 2, figs. 11, 12; pl. 6, figs. 10, 11.
Cytheridea (*Clithrocytheridea*) *garretti* STEPHENSON, *1936*, Jour. Paleontology, vol. 10, p. 702, pl. 94, figs. 5, 6, 10; text figs. 1 l, o, p.

This species, designated by me (Stephenson, 1936, p. 702) as the type for the subgenus *Clithrocytheridea*, shows some variation in size and shape in its occurrence at various stations in the Jackson Eocene. Specimens from the Claiborne here assigned to this species agree very closely with those from the Jackson, although they are smaller than most specimens in the upper Eocene beds. The figured specimen (pl. 18, fig. 1), a female carapace, is much higher and more tumid than males occurring in the same sediments. It appears impossible to differentiate a suite of Jackson specimens from material occurring in the Claiborne.

Length (female) 0.66 mm.; height 0.36 mm.; width 0.36 mm.

Occurrence.—Previously reported from the lower and basal portion of the Jackson Eocene, the present study has extended the range of the species into the Lisbon, underlying Claiborne of Alabama. I have identi-

fied no specimens, however, from the Claiborne of Louisiana.

Types.—Hypotypes, H. V. Howe coll., nos. 1590–1592, from the Lisbon of Alabama at Loc. 1 f.

CYTHERIDEA (CLITHROCYTHERIDEA) GOSPORTENSIS Stephenson, n. sp.
Plate 18, figures 5, 6

Carapace heavy, moderately tumid; in side view subpyriform, highest somewhat anterior to the middle. Anterior end broadly and obliquely rounded, faintly spinose near the ventral margin; posterior end fairly straight, compressed, and sloping rather gradually to the acute posteroventral angle. Dorsal margin somewhat concave, tending to form a saddle between the high, prominent anterodorsal angle and the lower, more obscure posterodorsal angle. Ventral margin straight to somewhat sinuous. Surface strongly sculptured, with a rather heavy ridge near and subparallel to the ventral margin, having its origin near the posteroventral angle, and extending to about the anterior one-third the shell length, where it merges with an irregular, thickened area of the shell wall. A second ridge, subparallel to the first across the center of the carapace and separated from it by a depressed area, extends from the anterior thickened shell area to about the posterior one-third the shell length, where another thickened, elevated area is usually visible. A rather heavy ridge around the anterior end and well inside it continues, somewhat reduced in prominence, around the dorsal margin, in some specimens merging with the posterior elevated area. Entire surface covered with rather small, fairly deep pits, many specimens showing larger, deeper pits on the more inflated portions. The pitting is continuous over the thickened areas of the shell wall, and the pits often carve into ridges. Hinge in the right valve consists of slender, high, terminal dental areas, faintly notched to form about three cusps, and truncated into a low, narrow groove between them, outlined dorsally by the low dorsal margin. Hinge in the left valve with well-incised, notched sockets, connected by a bar, which is separated from the dorsal margin by a broad depressed area. Marginal areas of moderate width, bearing about 25 simple radial pore canals on the anterior and about 10 on the posterior. The line of concrescence coincides with the inner margin throughout.

Length (right valve) 0.58 mm.; height 0.31 mm.; length (left valve) 0.58 mm.; height 0.32 mm.

Remarks.—*C.* (*C.*) *gosportensis* may easily be confused with *C.* (*C.*) *caldwellensis* Howe and Chambers (1935, pp. 11, 12, pl. 1, fig. 7; pl. 2, figs. 4–6), from the overlying Jackson Eocene. The Claiborne species is smaller, thinner, with finer pits and less pronounced sculpturing, more compressed posteriorly, and with a much more acute posteroventral angle.

Occurrence.—With the exception of occasional specimens from the Cane River of Louisiana (Loc. 11), this species is confined in my collections to the Claiborne of Alabama, where it is rather rare in the Lisbon and Gosport formations.

Types.—Syntypes, H. V. Howe coll., nos. 1593, 1594, from Loc. 1 a.

CYTHERIDEA (CLITHROCYTHERIDEA) OLIVERI (Cushman)
Plate 18, figures 19, 20

Cythere oliveri CUSHMAN, *1925*, Am. Assoc. Petroleum Geologists Bull., vol. 9, no. 2, p. 303, pl. 8, figs. 6–8.

Cytheridea müelleri STADNICHENKO (part), *1927*, Jour. Paleontology, vol. 1, pp. 238, 239, pl. 39, fig. 13 (not figs. 14–17).

Carapace tumid; in side view subquadrate. Dorsal margin straight or slightly indented, sloping very gently to the posterior, and subparallel to the straight or somewhat concave ventral margin. Anterior end broadly and evenly rounded, bearing about 10 very short, blunt, inconspicuous spines; posterior end somewhat narrower, sloping steeply to the blunt posteroventral angle, which is much more acute in the right valve than in the left. Entire surface closely covered with rather small, fairly deep pits, which often tend to become aligned in slightly depressed, curvilinear furrows near and subparallel to the periphery. Hinge in the right valve consists of slender, terminal, taxodont dental areas, faintly notched to form about four cusps. Between the dentitions is a well-incised, notched furrow, above which the low, rounded dorsal margin extends as a narrow ridge. In the left valve, hinge with well-incised, notched sockets, be-

tween which is a narrow, faintly notched bar, which is separated from the dorsal margin toward the posterior by a broad, shallow depressed area. Marginal areas fairly broad, bearing numerous straight, simple radial pore canals on anterior and posterior, with fewer visible along the entire ventral margin. The line of concrescence coincides with the inner margin except on anterior and posterior, where it extends somewhat within the marginal area. Muscle-scar pattern consists of a vertical row of four small scars, anterior to which are two additional scars, the dorsal of which is V-shaped.

Length (pl. 18, fig. 19), 0.57 mm.; height, 0.32 mm.; width, 0.27 mm.; length (pl. 18, fig. 20), 0.47 mm.; height, 0.27 mm.; width, 0.22 mm.

Occurrence.—I have specimens of this species from its type locality in Mexico (Loc. 19), and have found it to occur rarely in the Cook Mountain at Evergreen Crossing, Texas. In Louisiana, it is present in the Cook Mountain, occurring rarely at Locs. 3 and 7, and commonly at Locs. 4 and 6. I have no record of the species from the Cane River of Louisiana, nor from the Claiborne of Alabama. Specimens used for this study were collected at Loc. 6, with the exception of hypotype 1598, from Loc. 19.

Types.—Hypotypes, H. V. Howe coll., nos. 1595–1598.

Cytheridea (Clithrocytheridea) semireticulata Stephenson, n. sp.
Plate 18, figures 15, 16

Carapace rather heavy, tumid; in side view subquadrate. Anterior end obliquely rounded; posterior end slightly narrower, and steeply truncated to the rounded posteroventral angle. Dorsal margin weakly arched, straight along the hinge line, sloping gently toward the posterior, and subparallel to the straight or somewhat sinuated ventral margin. Entire surface rather strongly sculptured, with the ornamentation showing some variation. Near the ventral margin is a pronounced excavated area, horizontally elongated, and most prominent toward the posterior. The depressed area is enclosed ventrally by an irregular ridge, with a more prominent ridge of thickened clear shell material on its dorsal side. A somewhat depressed area dorsal to the central ridge is enclosed dorsally by an irregular, raised ridge. The shell wall is thickened just inside and parallel to the anterior margin, with a much more pronounced ridge well inside and subparallel to the posterior end. Entire surface except the peripheral area covered with irregularly disposed, rather shallow pits of variable size and shape. A variable reticulate pattern of ridges is visible over the tumid portion of the carapace, tending to branch and coalesce around the pits. Hinge structure of the right valve consists of slightly raised terminal dentitions, faintly notched to form about four cusps, between which is a well-incised, slightly crenulate trench, enclosed dorsally by the low dorsal margin. In the left valve, hinge with notched terminal sockets, joined by a slightly elevated, faintly notched bar, which is separated from the dorsal margin by a faintly incised line. Marginal areas fairly broad, with about 15 simple radial pore canals on the anterior, and fewer on the posterior. Line of concrescence coincides with the inner margin throughout.

Length (male), 0.57 mm.; height, 0.28 mm.; width, 0.26 mm.; length (female), 0.53 mm.; height, 0.31 mm.; width, 0.28 mm.

Remarks.—Sexual dimorphism is discernible in this species, with the female (pl. 18, fig. 16) shorter, higher, and more tumid than the male (pl. 18, fig. 15).

The new species shows some similarity to *C.* (*C.*) *nanafaliensis* Stephenson (1938, p. 578, pl. 67, figs. 9, 10), from the Wilcox Eocene of Alabama. It is much smaller in the adult, however, and much more strongly sculptured. It differs from *C.* (*H.*) *harrisi* Stephenson (1938, pp. 571, 572, pl. 67, figs. 11, 12) in the structure of the hinge line, the shorter, smaller carapace, the higher more steeply sloping posterior end, and more intense pitting.

Occurrence.—I have observed this species only in the Claiborne of Alabama. At Claiborne Bluff it is rare in the Gosport and Lisbon formations.

Types.—Holotype (complete specimen, male), H. V. Howe coll., no. 2275; paratypes, nos. 2276–2278. Type specimens were obtained from Loc. 1 e.

CYTHERIDEA (CLITHROCYTHERIDEA) SMITHVILLENSIS Stephenson, n. sp.
Plate 18, figure 2

Carapace tumid; in side view subreniform, highest slightly anterior to the middle, thickest at about the middle. Anterior end broadly and evenly rounded, posterior end narrower but well rounded. Dorsal margin weakly arched, flattened along the hinge line between the obscure cardinal angles; ventral margin nearly straight, slightly concave in the right valve. Surface nearly smooth, showing a very shallow, obscure pitting over tumid portions, which is often scarcely visible. A very fine, closely spaced, granular pitting, covering the entire exterior of the carapace, is superimposed over the larger depressions. Hinge in the right valve is composed of taxodont dental areas, cut into about four cusps by vertical notches, and truncated into a crenulate trench, outlined dorsally by the rounded bar of the dorsal margin. In the left valve, hinge with notched terminal sockets, between which is a low, finely notched bar, which is separated from the dorsal margin by a well-incised line. Marginal areas of moderate width, bearing about 10 simple radial pore canals on the anterior. Line of concrescence coincides with the inner margin throughout.

Length, 0.62 mm.; height, 0.35 mm.; width, 0.32 mm.

Remarks.—The new species is closely allied to *C.* (*C.*) *grigsbyi* Howe and Chambers (1935, pp. 15, 16, pl. 1, figs. 2, 3), and its several varieties. The Claiborne species is much smaller in the adult than typical specimens of *C.* (*C.*) *grigsbyi* from the overlying Jackson Eocene. The Jackson form likewise shows no tendency toward the larger, shallow pitting, but is finely and evenly pitted, with perforations larger than those of the Claiborne species. *C.* (*C.*) *grigsbyi* var. *vicksburgensis* Stephenson (1936, p. 703, pl. 94, fig. 8), an Oligocene form, exhibits much more pronounced, more closely spaced, fine pitting, with an almost complete absence of the larger, shallow pits. *C.* (*C.*) *grigsbyi* var. *chickasawhayana* Stephenson (1937, p. 155, pl. 26, fig. 12), from the Miocene, is a much larger, heavier form, showing a more pronounced fine pitting, and a slight tendency toward larger, shallow pits. *C.* (*C.*) *smithvillensis* is closely related to *C.* (*C.*) *tombigbeensis* Stephenson (1938, pp. 579, 580, pl. 67, figs. 1, 2), from the Wilcox Eocene of Alabama. The Wilcox species is slightly larger and higher, with a more pronounced fine pitting, and a more deeply impressed coarser pitting.

Occurrence.—The species is rare in the Gosport and Lisbon formations of Alabama at Loc. 1. It is represented by single specimens from Louisiana at Locs. 7 and 11. The type specimens were obtained from the Weches at Smithville, Texas, where the species is common.

Types.—Holotype (complete specimen), H. V. Howe coll., no. 2279; paratypes, nos. 2280, 2281.

CYTHERIDEA (CLITHROCYTHERIDEA) SUBPYRIFORMIS Sutton and Williams, var. WECHESENSIS Stephenson, n. var.
Plate 18, figure 14

Carapace small, fairly heavy; in side view subpyriform, highest slightly anterior to the center. Anterior end broadly and obliquely rounded; posterior end narrower, but well-rounded. Dorsal margin moderately well arched, flattened along the hinge line, and sloping toward the posterior; ventral margin nearly straight in the right valve, slightly convex in the left valve. Entire surface closely covered with rather small, deep pits, the pits being somewhat larger and more pronounced on the tumid central portion of the carapace. Hinge structure in the right valve consists of slightly elevated dental areas, faintly notched to form about six cusps. The terminal dentitions are truncated into a slender connecting trench, bounded dorsally by the low, rounded dorsal margin. Hinge in the left valve with notched terminal sockets, between which is a narrow bar, separated from the dorsal margin by a shallow depressed area. Marginal areas moderately broad, bearing about 20 straight, simple radial pore canals on the anterior, with fewer on the posterior and along the entire ventral margin. Line of concrescence coincides with the inner margin except on the anterior and posterior, where it extends nearly halfway into the marginal area.

Length, 0.52 mm.; height, 0.28 mm.; width, 0.26 mm.

Remarks.—This variety tends to be shorter and more blunt than the typical species. The "irregular pattern of reticulate ridges" described by Sutton and Williams (1939, p. 571) as being characteristic of the typical species is entirely lacking.

Occurrence.—I have observed this variety occurring with the typical species only at its type locality in the Weches formation at Smithville, Texas.

Types.—Holotype (complete specimen), H. V. Howe coll., no. 2282; paratypes, nos. 2283, 2284.

LOCALITIES

Loc. 1.—Outcrop of the Claiborne group, as exposed at Claiborne Bluff on Alabama River, Ala. Five samples from this locality have been examined, ranging at intervals along the face of the bluff.

a.—Gosport sand,[1] 10 feet above its contact with the underlying Lisbon formation. M. B. Stephenson Loc. 15.

b.—Lisbon formation 27 feet above the contact of beds 13 and 14 of the section of the bluff given by Smith (1894). This horizon carries very abundant specimens of *Ostrea sellaeformis* Conrad. M. B. Stephenson Loc. 14.

c.—Lisbon formation, 14 feet above the base of bed 13 of Smith. M. B. Stephenson Loc. 13.

d.—Lisbon formation, 8 feet above the base of bed 13 of Smith. M. B. Stephenson Loc. 12.

e.—Lisbon formation, exposed at water level, at top of bed 14 of Smith. M. B. Stephenson Loc. 10

Loc. 2.—Saline Bayou member of the Cook Mountain formation, exposed at St. Maurice, La.

Loc. 3.—Saline Bayou member of the Cook Mountain formation, in a ditch along a dirt road, 18 inches above base of slope leading down to Conley Creek, in the NE ¼ NE ¼ sec. 22, T. 10 N., R. 5 W., Winn Parish, La. J. Huner Loc. 62.

Loc. 4.—Milams member of the Cook Mountain formation, sampled in upper 2 feet of marl, 5 feet below top of slope leading down to creek branch, in a ditch on the south side of an improved road, in the SW ¼ SW ¼ sec. 28, T. 13 N., R. 3 W., Winn Parish, La. J. Huner Loc. 111.

Loc. 5.—Milams member of the Cook Mountain formation, at the same station as Loc. 4, but 12 feet below it, and 2 feet above the contact with weathered fossiliferous greensand. J. Huner Loc. 113.

Loc. 6.—Milams member of the Cook Mountain formation, in a drill hole 3 feet deep along an abandoned road, about 1½ miles northeast of the town of Calvin, in the SW ¼ NW¼ sec. 35, T. 12 N., R. 4 W., Winn Parish, La. J. Huner Loc. 119.

Loc. 7.—Milams member of the Cook Mountain formation, at its type locality. Sample collected at base of scarp, 6 inches below zone of limestone concretions, on southwest side of Antwine Creek, in the SW ¼ NE ¼ sec. 17, T. 13 N., R. 3 W., Winn Parish, La. J. Huner Loc. 213.

Loc. 8.—Basal Cook Mountain formation, at same station as Loc. 5, but 15 feet below it. Sample taken from a drill hole at depth of 5 feet. J. Huner Loc. 208.

Loc. 9.—Cane River formation at the type locality at Natchitoches, Natchitoches Parish, La. Sample taken at highway level.

Loc. 10.—Cane River formation exposed at Victoria Mills, in the SE ¼ NW ¼ sec. 19, T. 8 N., R. 8 W., Natchitoches Parish, La. This is the type locality of *Discocyclina advena* (Cushman). J. Rukas Loc. 221-B.

Loc. 11.—Oyster bed of the Cane River formation, exposed in the SW ¼ SE ¼ sec. 20, T. 8 N., R. 8 W., Natchitoches Parish, La. J. Rukas Loc. 226.

Loc. 12.—Top of the oyster bed of the Cane River formation, exposed in the SE ¼ NE ¼ sec. 24, T. 8 N., R. 9 W., Natchitoches Parish, La. J. Rukas Loc. 356.

Loc. 13.—Cane River formation at the type locality. Sample taken 17 to 20 feet below the oyster bed, ½ mile north of Natchitoches, Natchitoches Parish, La., on the highway. J. Rukas Loc. 503-B.

Loc. 14.—*Cyclammina* zone of the Cane River formation, at a depth of 30 to 40 feet in a hand dug well, in the NE ¼ sec. 35, T. 9 N., R. 7 W., Natchitoches Parish, La. J. Rukas Loc. 468.

Loc. 15.—Cook Mountain formation, exposed at Evergreen Crossing, Lee County, Tex. This is one of the localities from which Stadnichenko (1927) described Foraminifera and Ostracoda. Collected by A. D. Ellis, Jr.

Loc. 16.—Cook Mountain formation, at Orell's Crossing, Elm Creek, Lee County, Tex. (See Stadnichenko, 1927). Collected by A. D. Ellis, Jr.

Loc. 17.—Weches formation, exposed at Smithville, Bastrop County, Tex. Ostracoda from this locality were described by Sutton and Williams (1939). Five samples from this locality have been examined. J. B. Garrett Loc. 63.

Loc. 18.—Weches formation, exposed on Nacogdoches road, 6.5 miles west of San Augustine, San Augustine County, Tex. J. Rukas Loc. T-4.

Loc. 19.—Tempoal formation, exposed on Moctezuma River, state of Vera Cruz, Mexico. This is the locality from which Cushman (1925) described Foraminifera and Ostracoda. Collected by R. W. Barker.

[1] The "Gosport sand," which is separated from the underlying Lisbon formation by an unconformity, is classified by the U. S. Geological Survey as basal Jackson on the recommendation of C. W. Cooke. See JOUR. PALEONTOLOGY, vol. 13, no. 3, pp. 337–340. ED.

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NEW MIDDLE EOCENE GASTROPODS FROM CALIFORNIA

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ABSTRACT—Two new subgenera and three new species of gastropods from middle Eocene deposits of Ventura County, California, are described in this paper. Two of these are so similar to European middle Eocene species that they may be referrred to as analogous species. *Chedvillia* is here recognized as a good genus. M. Cossmann considered it a section under subgenus *Hippocrene*, which, in turn, he placed under the genus *Rostellaria* (=*Tibia*).

THE THREE SPECIES described in this paper come in a collection from the Llajas formation, middle Eocene, Ventura County, California. Two of them, *Chedvillia stewarti* and *Tibia* (*Eotibia*) *llajasensis*, were found in fine silts, which according to Mr. Frank Tolman come in the lower portion of the Llajas formation, while *Caliagaleodea californica*, n. sp., comes from higher up in the formation. These species are in collections made by Dr. Ralph Stewart in 1923, who at that time was an assistant in the Museum of Paleontology at the University of California. The first two species are described from outside casts made in the field. Two of these species belong to genera not reported previously from the Eocene of western North America. These are *Chedvillia stewarti* and *Tibia* (*Eotibia*) *llajasensis*, n. sp.; both are very similar to species found in the middle Eocene of Europe. As has already been pointed out by Clark and Vokes (1936), there are a considerable number of species from the middle Eocene of western North America that are undoubtedly closely related to European species, and which indicate that there had been an interchange between the faunas of those areas during that time. Two more species may now be added to the list of analogous species. No species similar to *Galeodea* (*Caligaleodea*) *californica* have been noted in the faunas of the European Eocene.

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Genus CHEDVILLIA (Cossmann), 1906

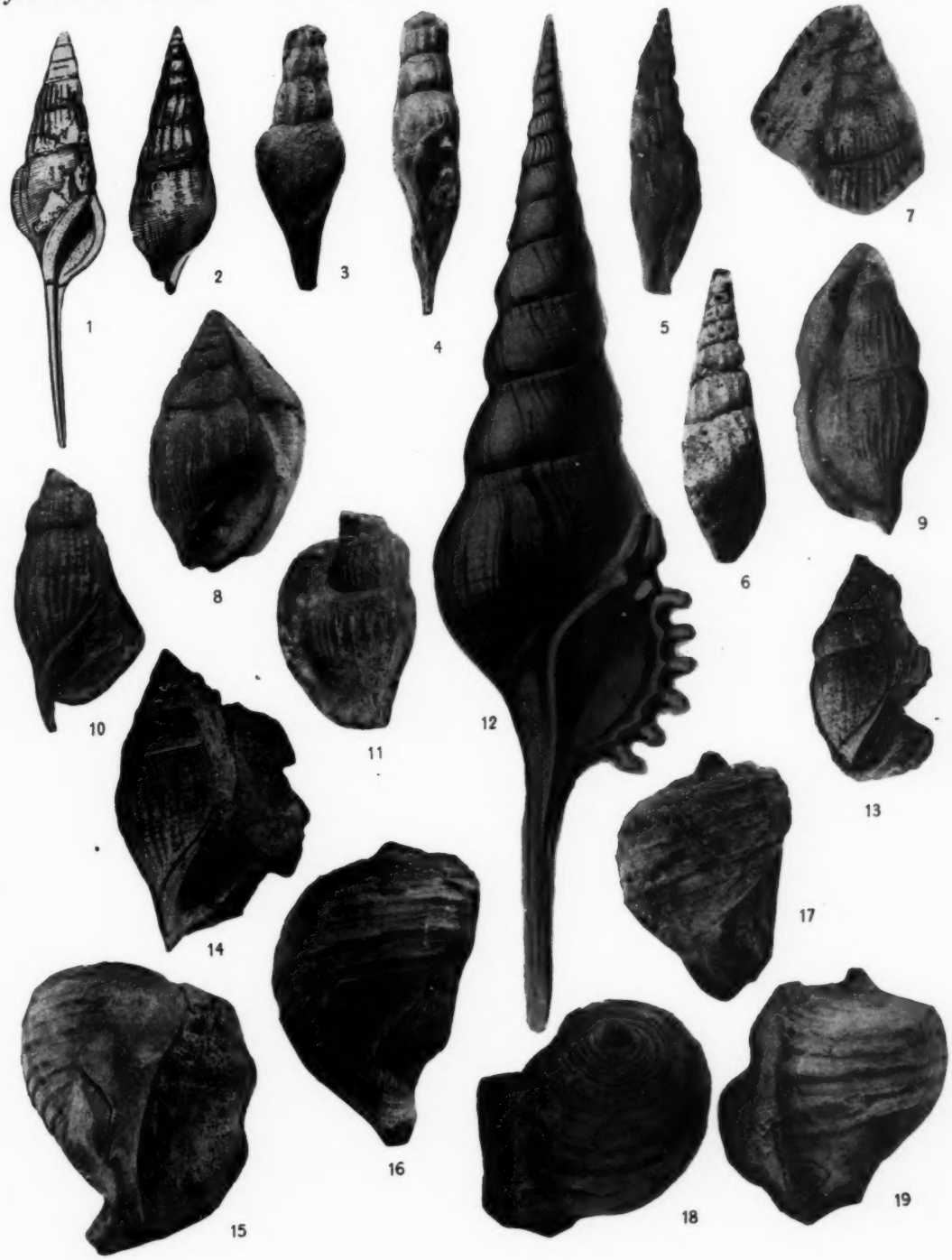
Genotype, *Rimella muneri* (*Chedville*), described as a new section of the genus *Rostellaria* (=*Tibia*) by Cossmann (1906).

The genotype of *Chedvillia* was placed by Cossmann as a section under the subgenus *Hippocrene*, which in turn was placed under the genus *Rostellaria*. In the writer's opinion, *Chedvillia* is worthy of generic rank. The type of aperture and posterior canal, together with the ribbing, show that it is more closely related to the genus *Rimella*, under which name it was originally described, than either to *Hippocrene* or *Rostellaria*. Cossmann considered that *Chedvillia* was intermediate in its characters between *Wateletia* and *Hippocrene*. The writer does not agree with this conclusion.

While both of those genera (subgenera according to Cossmann) have the same general type of flange on the outer lip as found on *Chedvillia*, they differ decidedly in other respects. *Hippocrene* and *Wateletia* have a fairly long, straight canal as is characteristic of *Tibia* (=*Rostellaria*). On *Chedvillia*, the

EXPLANATION OF PLATE 19

FIGS. *1, 2*—*Tibia* (*Eotibia*) *lucida* (J. Sowerby). Subgenotype of *Eotibia*. After Wrigley (1938). (p. 117)
3–6—*Tibia* (*Eotibia*) *llajasensis* Clark, n. sp. Univ. California loc. 7015. *3*, No. 34203, ×2.5; *4*, 34204, ×1.75; *5*, 34205, ×1.33; *6*, 34378, ×2. (p. 118)
7–11—*Chedvillia stewarti* Clark, n. sp. Univ. California loc. 7015. *7*, No. 34206, ×2; *8*, 34207, ×2; *9*, 34208, holotype, ×1.25; *10*, 34209, ×1.5; *11*, 34210, ×1.66. (p. 117)
12—*Tibia fusus* (Linne) = *Murex fusus* Linne. After Reeve (1851). (p. 117)
13, 14—*Chedvillia muneri* (Chedville). Genotype of *Chedvillia*. After Cossmann (1906). (p. 116)
15–19—*Galeodea* (*Caliagaleodea*) *californica* Clark, n. sp. Univ. California loc. 7004. *15, 16*, No. 34376, holotype, ×2; 34377, ×1. (p. 118)



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canal is very short, more like that of *Rimella*. The aperture of *Chedvillia* is more restricted than either of the other two genera, and it is more oblique to the axis of the shell. *Hippocrene* has a smooth outer surface, which stands out in marked contrast to the fine radial and spiral sculpture of *Chedvillia*. The sculpturing of *Wateletia* is much coarser and on all of the whorls even up to the apex a series of heavy, nodelike ribs cross from suture to suture on the whorls of the spire. A figure of *Chedvillia muneri* (Chedville), Cossmann's genotype, is shown in plate 19, figures 13, 14 of this paper. It will be noted that *C. stewarti*, n. sp., is very similar to that species in outline shape of the whorls, the character of the longitudinal and spiral sculpturing, and the short canal slightly twisted to the right. There can be little doubt that the two species are closely related.

CHEDVILLIA STEWARTI Clark, n. sp.
Plate 19, figures 7–11

Shell medium in size, fusiform in outline, apex acute, with 9 or 10 gently convex whorls; sutures slightly appressed; surface sculptured by numerous fine, closely spaced spiral lines, also by a series of fine longitudinal ribs, which are more numerous and finer on the posterior whorls of the spire than on the penultimate and body whorls of the adult specimens; these ribs a short distance below the suture on the body whorl of the adult specimens stand out more prominently and might be described as elongate nodes. Aperture elongate ovate, somewhat constricted, lying in an oblique position to the axis of the shell. Outer lip bordered by a broad, somewhat irregular flange, which usually extends from the anterior end of the canal to the apex and, when fully developed, as shown on the holotype, may be bordered by a fairly heavy, broad, low ridge. The fine spiral lines of the whorl extend out onto the flange; on the inner side of the flange posterior to the body whorl, similar to that on the genus *Rimella*, is a narrow open posterior canal, which extends up to the apex. Inner lip covered by a callus, which is heavier near the anterior end. Anterior canal short, slightly twisted to the right. All of the specimens at hand are plaster casts of external molds made in the field.

Dimensions.—Holotype, U. C. loc. 7015, no. 34208:[1] height, about 29.3 mm.; height of body whorl, about 15.6 mm. Paratype no. 34209: height, about 24 mm. (apex broken). Paratype no. 34210: height, about 28 mm. (apex broken). Paratype no. 34207: height, about 21 mm.; greatest width of body whorl, about 11 mm. (anterior end of canal broken). Paratype no. 34206, showing posterior end: height, about 10 mm.

Genus TIBIA Röding, 1798

Genotype, *Murex fusus* Linné (Dall 1906) = *Rostellaria* Lamarck, 1799, with same genotype.

Subgenus EOTIBIA Clark, n. subgen.

Genotype, "*Rostellaria?*" *lucida* J. Sowerby, 1815 = *Tibia lucida* (J. Sowerby).

In a recent paper, A. Wrigley (1938) has referred to the genus *Tibia* several species from Eocene deposits of England and Europe. In the writer's opinion, these are sufficiently different from the typical Tibias of the late Tertiary and Recent to warrant considering them as a distinct group of at least subgeneric rank. The name *Eotibia* is here proposed as a subgenus of *Tibia* for this group. The writer's attention was called to the distinctness of this group as a result of the discovery that one of the new species in our collections from the lower part of the Llajas formation, middle Eocene, of Ventura County, was very similar to one of the Eocene species of *Tibia* discussed by Mr. Wrigley; i.e., *Tibia lucida* (Edwards). In describing the subgenus, it seems best to select that species as the genotype rather than the West Coast species because of the better preservation of the former.

The new subgenus (see pl. 19, figs. 1, 2) may best be described by comparing it with the genotype *Tibia fusus* (see pl. 19, fig. 12), which has about twice as many whorls to the spire and is much more slender than the Eocene species. Also, on the former the longitudinal ribbing becomes obsolete on the anterior whorls of the spire and on the body whorl, and the spiral ribbing is represented only by faintly incised lines. On the Eocene species the spiral ribbing as well as the

[1] Locality and specimen numbers refer to collections in the Museum of Paleontology, University of California, Berkeley.

longitudinal ribbing is equally well developed on all the whorls. Another character that distinguishes the Eocene species is a series of irregular varices, which are not seen on any of the recent species of *Tibia*. However, the most distinctive characters that separate *Eotibia* from *Tibia* are found in the aperture. All of the recent species of *Tibia* show a denticulate outer lip and a well-developed posterior siphon, below which on the inner lip is a well-developed tooth. On the Eocene species of *Tibia*, the outer lip is not denticulate but sometimes bordered by a varix; there is only a faint indication of a posterior siphon, and there is no tooth on the inner lip. Both have a similarly shaped callus on the inner lip, and the canal is long, straight, and slender.

TIBIA (EOTIBIA) LLAJASENSIS
Clark, n. sp.
Plate 19, figures 3–6

Shell elongate, fusiform; spire high, slender, acute, with eight or nine whorls; sides of whorls gently convex; sutures depressed; surface covered by numerous fine, closely spaced, spiral lines; surface also sculptured by a series of moderately heavy longitudinal ribs, which on the whorls of the spire reach from suture to suture and well down onto the anterior end of the body whorl. On most of the specimens there is a series of irregularly spaced narrow varices which are best developed on the anterior whorls. Aperture elongate-ovate in outline, notched posteriorly; outer lip thin, or thickened by a varix; inner lip covered by a heavy, oblique, smooth callus, which on some specimens covers the anterior end of a varix. Anterior canal long, straight, and slender; all the specimens here figured are plaster casts of external molds.

Dimensions.—Holotype (apex gone), no. 34204: height, about 26 mm.; width of body whorl, about 5.5 mm. Paratype, no. 34378: height, about 22.5 mm.; greatest width of body whorl, about 8 mm. (canal broken). Paratype, no. 34205: height, about 30 mm. (anterior end of anterior canal broken). Paratype, no. 34203: height, about 11 mm. (anterior end and apex broken).

This species is very close in outline and general sculpturing to "*Tibia*" *sublucida* (Edwards), which is found in the London clay and Bracklesham beds, and is figured and discussed in the paper by Wrigley (1938).

Genus GALEODEA Link, 1807

Genotype, "*Buccinum*" *echinopora* Linné, figured by Thule (1929).

CALIAGALEODEA Clark, n. subgen.

Genotype, *Caliagaleodea californica* Clark, n. sp.

Shell thin, with low, acute, partly submerged spire; outer lip bordered by a broad, thin flangelike varix, which extends up into and joins the callus in the suture and that on the inner lip, which, in its middle portion, stands out away from the anterior canal as on *Cassis* and *Galeodea*. Canal moderately long, strongly flexed to the left, with a fairly well developed umbilical fasciole. Surface sculptured by fairly heavy rounded ribs, between which is a series of secondary and fine tertiary riblets.

The characters that distinguish *Caliagaleodea* from the typical *Galeodea* are as follows: The low, partially submerged spire; the fine secondary and tertiary spiral riblets between the main spiral ribs; the lack of noding; the thin, wide flangelike varix on the outer lip; the longer canal, which is twisted more strongly to the left than on the typical *Galeodea*. *Caliagaleodea* has a canal similar to that of the subgenus *Gomphopages* Gardner (1939) which differs in possessing a heavier shell, a body whorl with two prominent rows of nodes, and which is biangulate. On *Caliagaleodea* nodes are lacking, and the body whorl is more globose than on *Gomphopages*. The spiral sculpturing of the two is quite different; that of the latter consists of fine spiral lines, while on the former the major spiral ribs are fairly heavy, more like those on a typical *Galeodea*.

CALIAGALEODEA CALIFORNICA
Clark, n. sp.
Plate 19, figures 15–19

Shell thin, medium in size, globose with the three or four posterior whorls, forming a low but fairly acute spire above the broad, flattish upper surface of the shell formed by the body whorl and the first whorl of the spire, which, excepting the upper surface, is submerged. Surface sculptured by a series

of fairly heavy spiral ribs, which alternate somewhat irregularly in a tertiary, secondary, and primary series; on the anterior part of the body whorl, these ribs are finer than on the main part of the shell; there are about 16 major primary ribs on the body whorl of the holotype, only three of which are exposed on the submerged lower whorl of the spire. Surface of shell also sculptured by a series of fine longitudinal lines, which, in crossing the spirals, give the surface a reticulated appearance; on most of the specimens this reticulated sculpturing is not well preserved. Aperture elongate-ovate in outline; outer lip bordered by a wide, thin flange, which stands out almost at right angles to the main surface; on one of the specimens at hand, this flange is fully ¼ inch wide and extends up to the suture and joins with the heavy callus of the inner lip. Canal moderately long, rather strongly reflexed to the left; as viewed from the rear, it is rather broad; a well-developed umbilical fasciole at the end. Inner lip bordered by a thin platelike callus, which in the vicinity of the canal stands out away from the columella, leaving a fairly wide space between the two.

Dimensions.—Holotype, U. C. loc. 7004, no. 34376: height, 27 mm.; height of body whorl, 25.5 mm.; greatest width of body whorl, 24 mm. Paratype, no. 34377: height, about 29 mm. (apex broken); greatest width of body whorl, about 27 mm.

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 1, PP. 120–125, PL. 20, 2 TEXT FIGS., JANUARY 1942

PENNSYLVANIAN SCAPHOPODA AND CEPHALOPODA FROM NEW MEXICO

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ABSTRACT—A description is given of the scaphopod and cephalopod fauna of the Pennsylvanian Magdalena group of the northern Sangre de Cristo mountains of New Mexico. One new genus, *Prodentalium*, is erected; one new species of *Prodentalium*, three new species of *Huanghoceras*, and one new species each of *Pseudometacoceras*, *Mooreoceras*, and *Anthracoceras* are described.

THE CRYSTALLINE pre-Cambrian core of the Sangre de Cristo mountains of northern New Mexico is mantled by at least 4000 feet of sandstone, shale, and limestone of Pennsylvanian age. Locally, much of this sedimentary material has disappeared as a result of erosion. In the region from Las Vegas on the south to Red River on the north most, if not all, of these sediments of Pennsylvanian age belong to the Magdalena group. Sediments of Mesozoic age occur only along the complex eastern boundary of the range (Ray and Smith, 1941).

The writer has been engaged in a study of the stratigraphy and paleontology of the sediments of the Magdalena group of this region. The stratigraphy and correlation of this group will be discussed at a later time. The sediments carry abundant brachiopod and molluscan faunas. A few beds have yielded scaphopods and cephalopods. This paper, the first of a series on the paleontology of the Magdalena group of northern New Mexico, presents a discussion of the scaphopod and cephalopod faunas of the Pennsylvanian sediments in the region near Taos.

The writer wishes to express his sincere thanks to Prof. P. E. Raymond for his many helpful suggestions during the course of the work on this problem. The writer also thanks Mr. E. C. Cabot for the opportunity to study specimens of scaphopods and cephalopods collected by him from the Magdalena group. The field work of the summer of 1938 was made possible by a grant from the Bache Fund of the National Academy of Sciences.

All of the specimens mentioned in this paper are deposited in the Museum of Comparative Zoology, Cambridge, Massachusetts.

SYSTEMATIC DESCRIPTIONS

Class SCAPHOPODA

Family DENTALIIDAE

Genus PRODENTALIUM Young, n. gen.

Genotype, *Prodentalium raymondi* Young, n. sp.

This genus is proposed to include forms, formerly included in *Dentalium*, having many fine longitudinal lirae with a slightly zigzag alignment, as shown by *Prodentalium raymondi* (see pl. 20, figs. 4, 12). It is supposed that this zigzag alternation of direction of the lirae is a reflection of some fundamental characteristic of the mantle and is therefore of generic significance. The character of the slit of forms assigned to this genus is unknown.

The ornamentation of *Prodentalium* differs greatly from that of *Dentalium* s.s., which was based on a strongly ribbed form. *Dentalium* s.s. ranges only from Paleocene to Recent.

In addition to *P. raymondi*, *Dentalium semicostatum* Girty, described from the Wewoka of Oklahoma, is also referred to this genus.

PRODENTALIUM RAYMONDI Young, n. sp.
Plate 20, figures 3–6, 8, 12

Dentalium sp., Girty, *1903*, U. S. Geol. Survey Prof. Paper 16, p. 452.

Several specimens of unusually large scaphopods were given the writer to study by Mr. E. C. Cabot. These shells came from the carbonaceous shales near Talpa, New Mexico. In the summer of 1938, Mr. Cabot took the writer to the same locality, where more specimens of this species were col-

lected. The largest fragment measures 2.9 cm. in diameter, at the large end, which is not complete, and 12.5 cm. in length. It is estimated, from the rate of taper of the conch and from the examination of smaller fragments, that the total length of a conch having an anterior apertural diameter of about 3.0 cm. would be about 35.0 cm., by far the largest scaphopod ever described. The largest fragment shows a slight curvature. The shell is thick, averaging from 0.2 cm. to 0.4 cm. in thickness on large fragments, but is 0.1 cm. thick on small fragments. The shell is distinctly layered, new layers being added from the inside. As a result, fragments from posterior portions of adult conchs have a very thick shell. In thin or polished section, each layer can be followed from the inside until it terminates in a growth line on the external surface.

The exterior is marked by prominent transverse growth lines, slightly convex toward the anterior aperture on the dorsum, somewhat oblique laterally, and slightly concave toward the anterior aperture ventrally. The external surface is also marked by low, rounded, longitudinal ribs, which become obsolete toward the anterior aperture on mature individuals and are best developed posteriorly. These ribs show the peculiar zigzag development characteristic of the genus.

Several specimens of *P. raymondi* from the carbonaceous shales near Talpa have a much thicker shell than most of the smaller fragments. One such piece shows the test to have a thickness of 2 mm. where the diameter of the conch is but 7 mm., and in another specimen the thickness of the test is 3 mm. where the diameter of the conch is 1 cm. The largest of these small fragments is 3.3 cm. in length, with a diameter of 1 cm. at the larger end, and 0.8 cm. at the smaller end.

These thick-shelled, smaller fragments were at first believed to belong to a separate species, but on further study it appears likely that they are fragments broken from the posterior portions of mature specimens of *P. raymondi* (pl. 20, figs. 3, 5). The ornamentation on these fragments is very poor, probably the result of long-continued abrasion on the sea bottom. The thicker shell is believed to be the result of continued deposition of calcareous matter by the animal during its life.

Several other small fragments of *P. raymondi* were found with a much thinner shell (pl. 20, figs. 4, 6). One of these has a shell wall only 1 mm. in thickness for a conch 1.2 cm. in diameter. This shell has distinct longitudinal lirae. It is believed to be that of an immature individual. Neither apex nor aperture is present in either of these small specimens.

One fragment was found that shows the actual lip of the anterior aperture. This specimen (M.C.Z. 27943) is 10.4 cm. in length but is compressed laterally by compaction of the sediments in which it was found. The original diameter of the conch probably was between 3.0 and 3.3 cm. The actual anterior margin of the conch at the aperture is marked by a sharp, almost knifelike, ridge, but at a distance of only 1 cm. posterior to the anterior margin, the thickness of the conch is 0.5 cm. From this point the smooth interior surface of the conch slopes abruptly outward, so as to meet the exterior surface.

P. raymondi has been found in carbonaceous shales near Talpa, New Mexico, and in equivalent beds in Taos Canyon, about five miles farther north, in association with an abundant brachiopod and molluscan fauna. A similar form from the middle part of the Hermosa formation of the San Juan region of Colorado was described by Girty as *Dentalium* sp. Girty also referred to another large unnamed scaphopod of equal size from the Cisco group near Graham, Young County, Texas.

This species is named in honor of Prof. P. E. Raymond.

Class CEPHALOPODA

Order NAUTILOIDEA

Suborder ORTHOCHOANITES

Family ORTHOCERATIDAE

Genus MOOREOCERAS Miller, Dunbar and Condra, 1933

MOOREOCERAS OVALE Young, n. sp.

Plate 20, figures 10, 14

This species is described from a large incomplete specimen 11.5 cm. in length and 2.0 cm. in diameter at the larger end. Two smaller fragments of this form were also

found. The cross section is ovate. The conch gradually expands orad. Four camerae occupy a length equal to the diameter of the conch. The siphuncle is small where it passes through the slightly ovate, anteriorly concave septa but rapidly expands within the camerae. Diameter of siphuncle slightly less than length of camera. Convexity of siphuncle increases equally orad and apicad within the camera.

M. ovale differs from *M. normale* in that its cross section is ovate. It resembles *M. bakeri* but differs therefrom in that its siphuncle is not pyriform. All specimens found are from the carbonaceous shales near Talpa, where they were associated with *Prodentalium raymondi.*

Genus PSEUDORTHOCERAS Girty, 1911
PSEUDORTHOCERAS KNOXENSE (McChesney)

Orthoceras knoxensis McCHESNEY, *1860*, Description of new species of fossils, p. 69, (1859).
Pseudorthoceras knoxense GIRTY, *1911*, New York Acad. Sci. Annals, vol. 21, pp. 143–144.
Pseudorthoceras knoxense MILLER, DUNBAR and CONDRA, *1933*, Nebraska Geol. Surv. Bull. 9, ser. 2, pp. 81–85.

Several specimens whose characteristics are identical with those of the forms described by Miller, Dunbar, and Condra were observed in several of the carbonaceous shale beds near Talpa and in Taos Canyon (M.C.Z. 4078, 4079).

Genus LIROCERAS Teichert, 1940
LIROCERAS LIRATUM (Girty)

Coloceras liratum GIRTY, *1911*, New York Acad. Sci. Annals, vol. 21, p. 144.

A single small specimen consisting of one quarter whorl only is here referred to *L. liratum*. The cross section is somewhat reniform because of the high convexity of the venter and the concavity of the dorsum where impressed over the next adjacent whorl. At least 10 revolving lirae are present on each side and extend from the surface of the umbilical slope onto the extreme sides of the venter.

This specimen (M.C.Z. 4081) came from the carbonaceous shale bed that contained the fragments of *Anthracoceras multilineatum*, herein described.

LIROCERAS sp., cf. L. LIRATUM (Girty)

A single fragment of a tightly coiled nautilicone (MCZ 4082) showing nine chambers separated by eight sutures is here referred to *L. liratum*. Cross sections of chambers show them to be reniform in outline; the siphuncle is central; sutures are straight to slightly sinuous, with an incipient lobe on the venter. The umbilicus is apparently deep, with steep marginal walls. The specimen is completely exfoliated and therefore shows no external ornamentation. The impressed zone is probably from one-third to one-half the width of the preceding whorl. Although this fragment might be from a specimen of either *L. liratum* or *L. obsoletum*, it is here compared with *L. liratum*, solely because another specimen of that species has been definitely identified from the same bed.

This specimen came from the same bed as did the specimen of *L. liratum.*

Genus TEMNOCHEILUS M'Coy, 1844
TEMNOCHEILUS JOHNSONI Miller, Dunbar, and Condra
Text figure 1

Four fragments are referred to *T. johnsoni* because of the presence of large, well-developed nonconfluent nodes slightly elongated parallel to the long axis of the conch on the ventrolateral margin. Numerous growth lines traverse the lateral slopes and form distinct adapically directed convexities on the venter to mark the former position of the hyponomic sinus. The venter is marked by a gentle convexity in the region

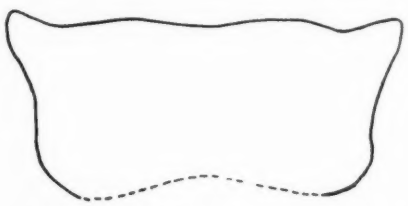

FIG. *1—Temnocheilus johnsoni* Miller, Dunbar, Condra, Diagrammatic cross section of M.C.Z. 4068, ×½, found near Talpa, N. Mex.

formerly occupied by the hyponomic sinus, as shown in text figure 1.

The fragments here referred to *T. john-*

soni came from the carbonaceous shales near Talpa and from beds at three different horizons in the Magdalena group in Taos Canyon, the highest some 1350 feet stratigraphically above the lowest.

This form was first described from beds of Pennsylvanian age in the Sangre de Cristo Mountains of Colorado, presumably from strata of the same age as the Magdalena.

This species closely resembles *T. winslowi* Meek and Worthen, *T. latus* Meek and Worthen, and *T. harneri* Miller and Owen. *T. johnsoni* differs from *T. winslowi* and *T. latus* in that the nodes are not confluent. It differs from *T. harneri* in that the nodes are distinctly flattened dorsoventrally.

All four of these closely related species are lower Pennsylvanian in age. *T. johnsoni* is distinct from the other three species, and all forms so far assigned to it are from either Colorado or New Mexico. The specimens of *T. johnsoni* found by the writer are from both the carbonaceous shales near Talpa and the *Anthracoceras*-bearing shales in Taos Canyon.

Genus HUANGHOCERAS
Yin, 1933

Huanghoceras simplicostatum GRABAU, *1922*, Geol. Surv. China, Bull. 4, p. 114, *nomen nudum* (in faunal list).
Huanghoceras simplicostatum GRABAU, *1924*, Stratigraphy of China, Part I, p. 377. *Nomen nudum* (in faunal list).
Huanghoceras Grabau YIN, *1933*, Palaeontologia Sinica, ser. B, vol. 11, fasc. 3, pp. 19–20.

Huanghoceras was first described by Yin in 1933, but attributed to Grabau. This genus was proposed to include those species of *Metacoceras* with well-developed transverse costae, which may or may not terminate ventrad or ventrad and dorsad, in nodes on the lateral borders of the conch. In addition to *H. simplicostatum*, the genotype, Grabau referred to *Huanghoceras* the species of Girty's *M. crassum* and *M. perelegans* group, *M. warchense* Reed, *M. falcatum* Sowerby, *M. costatum* Hind, and *M. percostatum* Bisat. Yin refers his new species *H. linchengense* to this genus. *H. simplicostatum* Grabau is first described in Yin's paper in 1933, although the name appeared twice previously in faunal lists.

HUANGHOCERAS OBLIQUICOSTATUM
Young, n. sp.
Plate 20, figure 2

The specimen on which this description is based is somewhat crushed, but the following characteristics were observed: Conch depressed, tarphyceraconic, sides straight to slightly convex, venter gently convex. Ornamented by ventroanteriorly directed lateral ribs, terminating at ventrolateral margin in prominent nodes.

This form differs from *H. crassum* in that the ribs are oblique rather than transverse. In the mature portion of the conch of *H. perelegans* the ribs are succeeded by dorsolateral and ventrolateral nodes.

The holotype of *H. obliquicostatum* consists of three whorls. The last adoral three ribs lack the terminal ventrolateral nodes. Siphuncle and sutures are unknown. Growth lines bend obliquely posteriorly as they ascend the umbilical wall, make a gentle V at the lateral umbilical border, and bend gently and obliquely forward to the ventrolateral margin, where they curve backward to form a deep, broad U, marking the former position of the hyponomic sinus.

All specimens of this form came from the lower part of the middle beds of the Magdalena group in Taos Canyon, where they were associated with *Mesolobus* sp., *Prodentalium raymondi*, *Anthracoceras multilineatum*, *Temnocheilus johnsoni*, *Marginifera haydenensis*, and other forms.

HUANGHOCERAS PERCOSTATUM
Young, n. sp.
Plate 20, figure 1

This specimen is based upon one specimen collected from the carbonaceous shales near Talpa by Mr. E. C. Cabot. This species resembles *H. obliquicostatum* but differs therefrom in its more compressed, less depressed conch and its stronger lateral ribs. It is also somewhat larger. It closely resembles *H. perelegans*, but differs therefrom in that the ribs are not resolved into two nodes at maturity.

HUANGHOCERAS COLLINUM Young, n. sp.
Plate 20, figures 9, 11

Though this species is based upon two whorl fragments only, the external orna-

mentation of the conch is so distinctive that the writer feels justified in describing it as new. The important characteristic is the possession of low, rounded, obliquely transverse lateral ridges, which are not nodose at either extremity. The sides of the conch are convex. A broad, deep hyponomic sinus is indicated by the direction of the growth lines on the convex venter. The umbilicus is large and moderately deep. Siphuncle and sutures were not observed.

The two fragments on which this description is based were found in the same carbonaceous shales that carried the specimens of *Anthracoceras multilineatum* Young, n. sp. Another fragment was found in the carbonaceous shales near Talpa.

Genus PSEUDOMETACOCERAS Miller, Dunbar, and Condra, 1933

PSEUDOMETACOCERAS VARIABILE Young, n. sp.

Plate 20, figure 7

As most of the fragments of this species are somewhat crushed, the dimensions of the specimens studied were somewhat distorted. However, the following description, based on two nearly complete and several fragmentary specimens is believed to be accurate.

Shell large, diameter 65 mm., discoidal. Umbilicus large, with diameter of 33 mm., equal to half the diameter of the conch. Cross section of adult whorl subhexagonal. At maturity, height of outer whorl is 1½ times to twice its width. Greatest width is at the umbilical shoulder. Venter flat, lateral surfaces gently concave toward the ventral margin, convex dorsally; umbonal slopes straight, steep; dorsum slightly impressed. Umbilical angle sharp, about 70°; ventrolateral angle sharp, slightly rounded. Umbilicus perforate.

Sutures have shallow lateral and ventral lobes and a distinct ventrolateral saddle. Growth lines indicate a deep hyponomic sinus. Moderately well developed ventrolateral nodes, somewhat elongated in a direction parallel to the growth of the conch, occur on the outer whorl of mature specimens.

This species is similar to *P. sculptile*, but differs therefrom by the more pronounced ventrolateral nodes on the outer whorl of the conch.

All known specimens of this form came from the carbonaceous shales near Talpa.

Class AMMONOIDEA

Subclass ANTHRACOCERATIDEA

Family ANTHRACOCERATIDAE Plummer and Scott, 1937

Genus ANTHRACOCERAS Frech, 1899

This genus includes, according to Plummer and Scott (1937):

compressed, narrowly umbilicate, finely striate small ammonoids having shapes like *Dimorphoceras*, but a much more primitive suture. The sculpture is like that of *Beyrichoceras* consisting of very fine evenly spaced transverse striae which bend forward a little in crossing the venter. The umbilicus is small and in some forms nearly closed. The suture line is the most characteristic feature. It consists of a broad ventral lobe divided by a short ventral saddle, a long rounded first lateral saddle, a medium sized rounded lateral lobe and a broad, rounded second lateral

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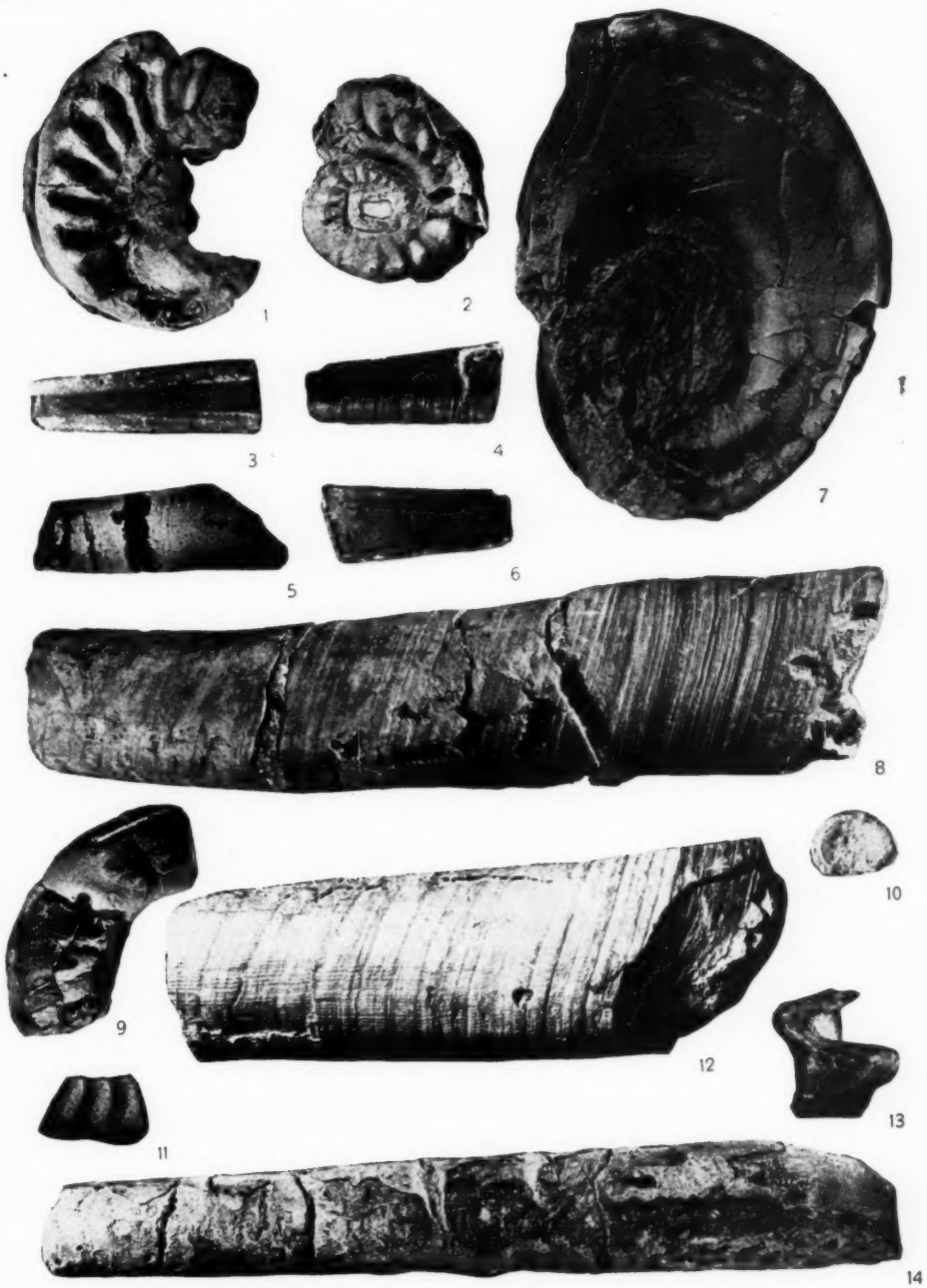
EXPLANATION OF PLATE 20

FIG. *1*—*Huanghoceras percostatum* Young, n. sp. Holotype, M.C.Z. 4070, ×1. (p. 123)
2—*Huanghoceras obliquicostatum* Young, n. sp. Holotype, M.C.Z. 4069, ×1. (p. 123)
3–6, 8, 12— *Prodentalium raymondi* Young, n. sp. *3*, Longitudinal section through adapical part of mature individual, showing thickened shell walls; M.C.Z. 27940, ×1. *4*, Exterior of fragment of immature individual, showing longitudinal lirae; M.C.Z. 27941, ×1. *5*, Exterior of mature individual, showing almost smooth shell surface; M.C.Z. 27942, ×1. *6*, Longitudinal section of specimen shown in Fig. 4, illustrating thin shell walls of immature form. ×1. *8*, The holotype; M.C.Z. 27938, ×1. *12*, Another large specimen, showing external markings; M.C.Z. 27938, ×1. (p. 120)
7—*Pseudometacoceras variabile* Young, n. sp. Holotype; M.C.Z. 4073, ×1. (p. 124)
9, 11—*Huanghoceras collinum* Young, n. sp. *9*, Partly exfoliated part of outer whorl of holotype; M.C.Z. 4071, ×1. *11*, Fragment of exfoliated shell; M.C.Z. 4072, ×1. (p. 123)
10, 14—*Mooreoceras ovale* Young, n. sp. *10*, Cross section of small fragment, showing ovate outline; M.C.Z. 4067, ×1. *14*, The holotype; M.C.Z. 4066, ×1. (p. 121)
13—*Anthracoceras multilineatum* Young, n. sp. The holotype; M.C.Z. 4075, ×1. (p. 124)



Young, Pennsylvanian Scaphopoda and Cephalopoda

saddle. It is distinguished from *Beyrichoceras* by its rounded lateral lobe, and from *Homoceras* by its rounded lobe and much smaller umbilicus, from *Cravenoceras* by its rounded lobe, lesser thickness, and narrower umbilicus. It resembles most in shape *Dimorphoceras* but has a much simpler suture line.

ANTHRACOCERAS MULTILINEATUM
Young, n. sp.
Text figure 2; plate 20, figure 13

Two fragments representing a single species are the only traces of ammonoid cephalopods found by the writer in the Magdalena group. *Goniloboceras goniolobus* has been reported from Caballero Canyon, just east of Alamogordo, New Mexico, in the Magdalena, just below the base of the Abo (Darton, 1928).

A. multilineatum resembles *A. wanlessi* but is larger. As this species is known only from two small fragments, it is impossible to give the exact dimensions of the mature form. The height of the last whorl is at least 20 mm., probably somewhat greater, and

FIG. 2—*Anthrococeras multilineatum* Young, n. sp. External suture line, ×1.

the greatest thickness is probably near 15 mm. As the sutures of the holotype are very close together, the fragment is probably from near the aperture of a mature individual. The surface is marked by numerous closely spaced lirae of growth averaging about 130 to the centimeter. The sutures resemble those of *A. wanlessi*, but the lobes and saddles are somewhat stronger and less rounded. The first lateral lobes extend beyond the bifid ventral lobe to a greater extent than do those of *A. wanlessi*. The two fragments of this species came from carbonaceous shale beds low in the Magdalena section in Taos Canyon, where they were associated with *Temnocheilus johnsoni*, *Huanghoceras collinum*, *H. obliquicostatum*, and a small brachiopod fauna, including a species of *Mesolobus*.

Genus ENDOLOBUS Meek
and Worthen, 1865

ENDOLOBUS sp.

Four nearly complete but rather badly crushed specimens of *Endolobus* were given the writer to study by Mr. E. C. Cabot. The writer also collected numerous fragments and several nearly complete specimens that are here referred to *Endolobus*. These specimens are also characterized by low, broad, conical nodes on the lateral surfaces. Their general proportions are the same as those of the genotype, *E. spectabilis* (Meek and Worthen). The diameter of the conch ranges from 10 to 18 cm.

One specimen came from sec. 11, T. 25 N., R. 15 E., near Agua Fria, several came from the carbonaceous shales near Talpa, and a few fragments were found in several beds of carbonaceous shale in Taos Canyon.

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JURASSIC CORALS FROM THE SMACKOVER LIMESTONE, ARKANSAS

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ABSTRACT.—Two new species of scleractinian corals, *Thamnasteria imlayi* and *Stylina arkansasensis*, are described from the Middle or Upper Jurassic Smackover limestone in deep wells in Columbia County, Arkansas.

INTRODUCTION

FROM the subsurface Jurassic Smackover limestone in deep wells in southern Arkansas specimens of scleractinian corals have been recovered. All are preserved as external molds with the exception of two ramose specimens, which are completely replaced by fibrous crystalline anhydrite and thereby rendered quite indeterminable. The molds are fairly good and show well the superficial features, which, however, alone are usually insufficient for the close identification of corals. Of the six different corals represented, one solitary form and five colonial types, only two colonial corals, both new species, can be determined. They are described below as *Thamnasteria imlayi* and *Stylina arkansasensis*. The small solitary turbinate coral (UM 22159) appears to be an immature *Montlivaltia*, while the three new colonial forms represent as many species of two genera—one probably of *Astrocoenia* (plate 21, fig. 5) (UM 22157), two of *Isastrea*, a small digitate species (plate 21, fig. 6) (UM 22160) and a larger submassive (?) one (UM 22158).

The occurrence of corals in the Smackover limestone has been discussed recently by Imlay (1940, pp. 20–21), and preliminary study of some of the specimens by Dr. T. Wayland Vaughan indicated the presence of *Thamnasteria*.

The age of the Smackover limestone is Middle or Upper Jurassic, according to Imlay (1940, p. 19), and there is little information bearing on this point to be gained from the corals. One of the two new species is most closely allied to Middle Jurassic European species, whereas the other finds close comparison only with an Upper Jurassic species from the same area. Corals occur in the Jurassic rocks of Mexico (Burckhardt, 1930, pp. 51, 61, 65, 86), in the *Nerinea* limestone of Oxfordian age in Mazapil, San Pedro del Gallo, and elsewhere, but none has yet been described and no comparisons can be made at this time.

The writer wishes to express his thanks to Dr. R. W. Imlay for the opportunity of studying this most interesting lot of corals. All specimens are deposited in the Museum of Paleontology, University of Michigan (UM).

BIONOMIC NOTE

Imlay considers (1940, p. 20) that the Smackover limestone accumulated in a shallow transgressing sea marked by fringing reefs. The commonest corals, new species of *Stylina* and *Thamnasteria*, have a dendroid or ramose growth form, and evidently formed low bushy clumps. The lack of massive, nodular, or encrusting forms suggests growth either in the quiet, very shallow waters of lagoons or in deeper water (15 feet or more) undisturbed by the surf. One of the four indeterminable corals, a solitary turbinate form (probably *Montlivaltia*), was either free or with a very small and insecure basal attachment, a condition further suggestive of an undisturbed environment. Certainly the corals did not live in agitated water or on the shallower parts of the seaward margins of reefs. Imlay notes the absence of definitely ascertained back reef deposits and remarks that

> fringing reefs which rise only a few feet above the sea floor and which grow close to the shore need not have an appreciable thickness of back reef deposits.

He compares them with the fringing reefs of the Jurassic of England described by Arkell (1933, pp. 557–562; and 1935), but in these, as described so well by Arkell, and where they were seen in the vicinity of Oxford by

the writer in 1933, the main reef builders appear to have been massive species of *Thamnasteria* and *Isastrea*, with fasciculate and fairly sturdy colonies of *Thecosmilia* and *Calamophyllia* (*Rhabdophyllia*) flourishing in less exposed situations. On the basis of present evidence it may be doubted whether there were reefs of any sort in the Smackover sea in southern Arkansas—the presence of reef-building corals does not of course indicate the development of reefs. Probably the corals grew rather thinly and in scattered patches some distance from shore on a bottom sloping gently seaward.

DESCRIPTIONS OF SPECIES

Family THAMNASTERIIDAE

Genus THAMNASTERIA Lesauvage, 1823

THAMNASTERIA IMLAYI Wells, n. sp.

Plate 21, figures 1–3

Corallum ramose, branching irregularly at angles of 70°–80°, branches tapering gradually to an obtuse point, ranging in diameter from 10 to 20 mm., 5 mm. near the tips. Corallites more or less regularly arranged, spaced from 1.5 to 2.0 mm. between calicular centers. Calyces circular or oval with shallow fossettes, united directly by stout confluent costae. Calicular diameter averaging 1.25 mm. Septa moderately thick, imperforate, varying in number from 20 to 24, usually 20, irregularly arranged, but with half (10–12) extending to the columella, the remainder usually extending less than halfway and uniting with the longer septa. Columella a stout, styliform rod, prominent in the bottom of the fossette. Internal structure quite unknown.

Types.—Smackover limestone, 85–97 feet below the top, depth of 7580–7592 feet in Atlantic Refining Co., Spain No. 2 Well, sec. 19, T. 17 S., R. 19 W., Columbia County, Arkansas. Holotype (UM 22150) and three paratypes (UM 22152).

Other occurrences.—Smackover limestone, depths of 7564–7565 feet (one specimen UM 22154), 7565–7566 feet (seven specimens, one figured, UM 22151), 7566–7567 feet (seven specimens, UM 22153), and 7591–7592 feet (two specimens, UM 22155), Atlantic Refining Co., Spain No. 1 Well, sec. 18, T. 17 S., R. 19 W., Columbia County, Arkansas.

Remarks.—Dendroid corals of this genus are uncommon, most species being encrusting, nodular, subdigitate, or massive. The two species known from the Lower Cretaceous of Texas, *T. vaughani* Wells (1932, p. 247, pl. 36, figs. 1–3) from the lower Glen Rose formation, and *T. hoffmeisteri* Wells (1933, p. 180, pl. 2, fig. 21, pl. 10, figs. 18, 19) from the Buda limestone, are both massive or encrusting (*T. vaughani* may be digitate). Otherwise *T. vaughani* is very similar to *T. imlayi; T. hoffmeisteri* has centers about 3 mm. apart, with rarely more than 18 septa. There are no species of the genus known to the writer occurring in the American Jurassic, nor is he aware of any ramose species elsewhere from the Lower Cretaceous, with the exception of *T. index* (de Fromentel) (1861, p. 217) from the Neocomian of France (Saint-Dizier), which apparently has a strictly decameral septal arrangement. Ramose Jurassic species are few, but from the Middle and Upper Jurassic the following having about the same number of septa and nearly similar dimensions should be noted: *T. dendroidea* (Lamouroux) (1821, p. 85, pl. 78, fig. 6), the genotype by monotypy, from the Bajocian at Caen (Calvados), *T. lyelli* Milne Edwards and Haime (1851, p. 118, pl. 21, fig. 4) and *T. waltoni* Milne Edwards and Haime (1851, p. 120, pl. 25, fig. 4), both from the Great Oolite (Bathonian) of England, *T. digitata* (Defrance) (1826, p. 386, and Michelin, 1845, p. 227, pl. 54, fig. 15) from the Bajocian at Caen, and *T. arborescens* Étallon (1859, p. 615) from the Sequanian at Valfin. *T. imlayi*, so far as can be determined from the imperfect specimens, is nearest *T. waltoni*, except that this species has a tubercular rather than styliform columella, a minor difference.[1] It may also be related to *T. digitata*, but this has slightly smaller and more closely set corallites and thinner branches. The other

[1] Another distinction between *T. waltoni* and *T. imlayi* may be in the growth form. In 1883 Tomes (*Geol. Soc. London Quart. Jour.*, vol. 39, p. 189) indicated that the English species has a digitate rather than ramose growth form. In the same paper Tomes (pp. 188–189) described *T. microphylla*, another ramose species with very small calyces and three complete cycles of septa, 24 in all. This, however, may not be *Thamnasteria*, for Tomes notes that "none of the costae anastamose," *i.e.*, that the costae are nonconfluent.

species mentioned above all have slightly larger calices.

The small specimen figured on plate 21, figure 5, might appear to belong to this species, but the calyces are smaller, averaging 0.75 mm. in diameter, with fewer septa (12) and thick, solid walls. It might be either *Astrocoenia* or *Stephanocoenia* but is too badly worn to be further determinable. The specimen came from the upper part of the Smackover limestone in the Mahony No. 1 Riley Well, Atlanta pool, southeastern Columbia County, Arkansas (UM 22157).

Family STYLINIDAE

Genus STYLINA Lamarck 1816

STYLINA ARKANSASENSIS Wells, n. sp.

Plate 21, figure 4

Corallum ramose, with cylindrical branches about 12.5 mm. in diameter. Corallites fairly regularly arranged, from 2.0 to 2.5 mm. apart between centers. Calyces circular, projecting very slightly, averaging 1.5 mm. in diameter, with small fossette, united across the intercorallite spaces by more or less confluent, thick, low and rounded costae. Septa in three complete cycles (24), those of the first (6) large and prominent, extending to the columella; those of the second (6) smaller and shorter, internally free; and those of the third (12) very short, regularly united to those of the second cycle. Columella a strong style at the bottom of the calyx. Internal structures quite unknown.

Type.—Smackover limestone 85–97 feet below the top, depth of 7580–7592 feet in Atlantic Refining Co., Spain No. 2 Well, sec. 19, T. 17 S., R. 19 W., Columbia County, Arkansas. (Holotype, UM 22156).

Remarks.—The only specimen of this species is part of a stout branch 50 mm. long with traces of a branchlet at one end at an angle of about 30° or less. The colonies probably formed clumps with nearly erect branches, similar to the living *Porites furcata* of the West Indies, a species very common in shallow, well-protected lagoons and reef flats.

Most species of *Stylina*, like *Thamnasteria*, have massive or nodular growth forms, and ramose types are most uncommon. *S. intricata* de Fromentel (1862, p. 31, pl. 3, figs. 5, 5a), from the Portlandian of France, resembles the Smackover species but has more protuberant calyces and thinner septa arranged in but two complete cycles (12). *S. arborea* d'Achiardi (1880, p. 58, pl. 19, fig. 8), of the Italian Portlandian, also has only two septal cycles. Ogilvie (1896, p. 169, pl. 17, figs. 1, 1a) referred to *S. arborea* a species from the Portlandian of Stramberg, but her figures show three distinct cycles of septa, those of the third apparently not uniting with those of the second, but otherwise, except for thicker branches, very close to *S. arkansasensis*.

Gregory's *Dendroseris harrisoni* (1929, p. 66, pl. 8) from the middle Cretaceous (?) Bousignac limestone of Trinidad, is another digitate species of *Stylina*, readily distinguished by only two cycles of septa and smaller corallites (1–1.25 mm.).

Six species of *Stylina* were listed from the Upper Jurassic Hinchman formation of California by Hyatt (1892, p. 408): *S. tubulifera* (Goldfuss), *S. subjecta* Hyatt (near *S. echinulata* (Lamarck)), *S. alba* Hyatt, *S. minuta* Hyatt (near *S. geminata* Milne Edwards and Haime), *S. intermedia* Hyatt, and *S. tertia* Hyatt. Hyatt's species have never been described or figured, and his names remain *nomina nuda*, although Crickmay (1933, p. 901) changed the generic assignment of several of them (*Astrocoenia minuta*, *A. subjecta*, and *Stephanocoenia tertia*) without printed comment, and it is fruitless to

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EXPLANATION OF PLATE 21

All figures except *1* are from rubber casts.

FIGS. *1–3*—*Thamnasteria imlayi* Wells, n. sp. *1*, Mold of holotype at upper right; the forked white patch is an anhydrite replacement of a coral branch probably of the same species; well cutting from the Smackover limestone at a depth of 7580–7592 feet, Columbia County, Ark., UM 22150, ×1. *2*, Cast of holotype, ×2.3. *3*, Cast of homeotype, UM 22151, ×2.3. (p. 127)

4—*Stylina arkansasensis* Wells, n. sp. Cast of holotype, UM 22156, ×2.3. (p. 128)

5—*Astrocoenia?* sp. Cast of worn specimen, UM 22157, ×2.3. (p. 126)

6—*Isastrea* sp. Cast of specimen of small species, UM 22160, ×2.3. (p. 126)

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compare them with *S. arkansasensis*, except to remark that most of them have massive coralla.

One more American species of *Stylina* should be mentioned here: *S. collinsi* Gregory (1899, p. 460, fig. 3), from the Neocomian of San Luis Potosí, Mexico, with massive-nodular growth form, 12–24 septa, and calyces 1.2–2.0 mm. in diameter, 3–3.5 mm. between centers.

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 1, PP. 130–132, PL. 22, 1 TEXT FIG., January 1942

NOTES ON THE CEPHALOPOD LAMBEOCERAS LAMBEI FROM MANITOBA

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ABSTRACT—A very large specimen of *Lambeoceras lambei* (Whiteaves) from Garson, Manitoba, is described. It measures 45.5 inches in length. The characteristic structures and calcareous deposits of an actinoceroid siphuncle are shown to be present in the genotype species. Growth lines and the form of the hyponomic sinus are also described.

Gonioceras lambei Whiteaves, the genotype selected by Foerste for his cephalopod genus *Lambeoceras*, was found in the quarry on the Seller farm at East Selkirk, Manitoba. Apparently only one specimen was available to Whiteaves (1892) for his description of *G. lambei*, and this specimen was used by Foerste (1929) for his description of *Lambeoceras lambei* (Whiteaves). The quarry at East Selkirk has been abandoned for many years, and the Selkirk member of the Red River formation (Upper Ordovician), in which the genotype specimen was found, is very largely covered. Excellent exposures, however, of the Selkirk member appear in the quarries at Garson, approximately six miles southeast of East Selkirk. Collections of fossils made here by members of the Natural History Society of Manitoba and the writer contain several interesting specimens of *L. lambei*.

Although the lines of growth and the hyponomic sinus have never been observed in *Lambeoceras*, it has always been assumed that the siphonal side is the ventral side. According to Miller (1932) the aperture of his species *L. peculiare*, as indicated by the small part of the aperture preserved near the central part of the ventral side of an internal mold, was simple, straight, and lacked the hyponomic sinus. The aperture of *Lambeoceras* from Manitoba has not, as yet, been observed. A small specimen, probably an immature individual rather than a fragment of a large test, which is believed to be conspecific with *L. lambei*, is the only test collected at Garson with the growth lines preserved over its surface. The growth lines are well preserved on the antisiphonal side (pl. 22, fig. 2) where they form wide gentle crests. Only a few incomplete growth lines are preserved on the siphonal side (pl. 22, fig. 4) but it seems apparent, from their direction of growth, that they formed wide shallow sinuses on this side. A hyponomic sinus and dorsal crest are thus indicated for the aperture of *L. lambei*. The ventral side, as has been correctly assumed by authors, is on the siphonal side.

The lines of growth, described above, are spaced somewhat widely apart and form the only ornamentation of *L. lambei*.

One of the most interesting specimens collected is a very large internal mold of *L. lambei* with small patches of shell still adhering to the mold. This specimen is believed to be a record as to size for members of the family Goniocerati dae. Troedsson (1926*a*) has recorded a very large specimen of *Gonioceras groenlandicum* Troedsson which he described as being over 400 millimeters and probably not less than 430 millimeters in length. The Garson specimen of *L. lambei* (pl. 22, figs. 5–7) is 1155 millimeters (45.5 inches) long, of which 910 millimeters represent the incomplete phragmacone composed of 89 camerae, and 245 millimeters the living chamber. Although the aperture is not preserved, very little of the living chamber appears to be missing. Compared with another large specimen in the University of Manitoba collections it is estimated that between 200 and 250 millimeters of the apical part of the phragmacone has been lost. This would give a possible total length of at least 1405 millimeters (54 inches) for a restored specimen. The lateral diameter enlarges from 73 millimeters (3 inches) at the apical end of the specimen to 228 millimeters (9 inches) at the base of the living chamber. At the oral end the lateral diameter measures 228 millimeters, but the

specimen is partly worn away at this point, and the maximum lateral diameter is estimated to have been at least 235 millimeters. The ventrodorsal diameter at a distance of 105 millimeters from the apical end of the specimen is approximately 32 millimeters (1.3 inches) and at the base of the living chamber it is approximately 65 millimeters (2.6 inches). For comparison of size with the described species of *Lambeoceras* and *Gonioceras groenlandicum* the following table of measurements is added:

	Length (in mm.)	Lateral Diameter (in mm.)
L. lambei (Whiteaves)		
Genotype specimen	265	172
Garson specimen	1155	228
L. confertum Foerste, Minnesota	195	
L. peculiare Miller, Wyoming	99	54
L. cultratum Miller, Wyoming	117	87
L. landerense Foerste, Wyoming	140	107
L. acutilaterale Foerste, Wyoming	70	55
L. boreum Troedsson, Greenland		90–110
L. princeps Troedsson, Greenland	400	170
L. nudum Troedsson, Greenland		95
L. magnum Troedsson, Greenland		140
L. articum Teichert, Arctic Canada		65
Gonioceras groenlandicum Troedsson, Greenland	430	190

The siphuncular deposits of *Lambeoceras* from Greenland were fully described and illustrated in 1926 by Troedsson (1926*b*). It is interesting to note that several years later Foerste (1929) redescribed the genotype species and in his generic diagnosis of *Lambeoceras* stated that

> The siphuncle is actinoceroid in appearance, but *contains no calcareous deposits, though such deposits appear to occur* [italics mine] in the species described by Gustaf Troedsson from the Ordovician of Northwest Greenland.

Every adult or mature specimen of *L. lambei* collected at Garson that has been sectioned shows a very remarkable development of the calcareous deposits, endosiphuncular tube, radial canals and other typical actinoceroid structures (pl. 22, fig. 3, text fig. 1). The calcareous deposits and other siphuncular structures are very similar to those described and illustrated by Troedsson for his species of *Lambeoceras* from Greenland. It should be noted that Teichert (1933*a*) in 1933 also stated that there were no calcareous deposits (obstruction rings) in the siphuncle of the genotype species *L. lambei*. The illustration of *L. lambei* given by Foerste (1929) in his publication on the cephalopods of southern Manitoba is reproduced (pl. 22, fig. 1) so that a comparison may be made with a large longitudinally

FIG. 1—*Lambeoceras lambei* (Whiteaves). Longitudinal section to show siphuncular deposits at the apical end, ×½; Garson, Manitoba; Univ. Manitoba 103.

sectioned specimen from Garson (text fig. 1) Both figures are reduced to one-fifth the natural diameter. It seems quite evident to the writer that the longitudinal section made in the genotype specimen did not cut into the apical part of the siphuncle where the calcareous material was deposited in the form of obstruction rings, or that the apical part of the genotype specimen as preserved is above the zone where the obstruction rings were formed. There is no generic difference, as one might possibly infer from the Foerste diagnosis, between the Manitoba and Greenland *Lambeoceras*.

Although typical actinoceroid features are present in *Lambeoceras*, Troedsson (1926*c*) placed the genus with the Orthochoanites rather than with the Cyrtochoanites because of the straight septal necks. Foerste and

Teichert (1930), however, considered *Lambeoceras* to be in the order Cyrtochoanites as a member of the family Gonioceratidae. Teichert (1933*b*, 1934), several years after Troedsson's work, discovered that the septal necks in the genotype specimen and the Greenland species of *Lambeoceras* are not straight as in the Orthochoanites, but are bent outwards as in the Cyrtochoanites. The straight appearance of the septal necks is due, according to Teichert, to the diagenetic recrystallization of calcite. A study of several thin sections of the siphuncles of *L. lambei* from Garson confirms Teichert's observation. The majority of the septal necks appear to be straight, but an occasional one with the recurving brim can be observed.

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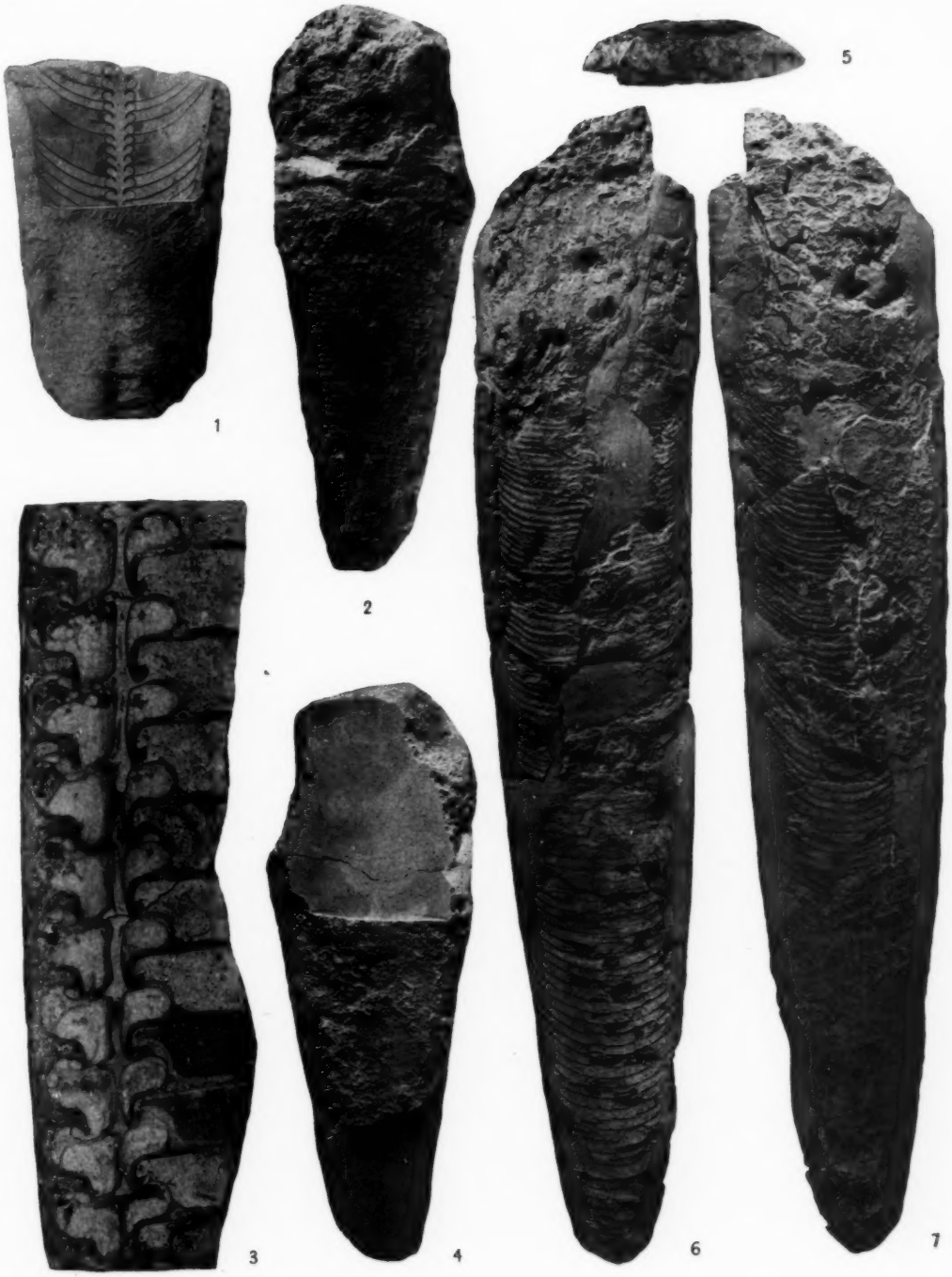
EXPLANATION OF PLATE 22

FIGS. *1–7*—*Lambeoceras lambei* (Whiteaves). *1*, Ventral view, ×½; East Selkirk, Manitoba; after Foerste. *2*, *4*, Dorsal and ventral views, ×½; Garson (?), Manitoba; Univ. Manitoba 101. *3*, Longitudinal section of siphuncle, ventral side on left, ×1; Garson, Manitoba; Univ. Manitoba 104. *5–7*, Oral, dorsal and ventral views, ×⅐; Garson, Manitoba; Univ. Manitoba 102.



Leith, *Lambeoceras lambei* (Whiteaves)

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 1, PP. 133–134, 1 TEXT FIG., JANUARY 1942

NEW RESTORATION OF A HOODED DUCK-BILLED DINOSAUR

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SEVERAL restoration models of dinosaurs have been executed, but for many of them the student did not have well-preserved, uncrushed specimens from which to work, or the models were made on such a small scale that details were not possible. The writer recently completed a scale model of the head of *Corythosaurus* in which particular attention was given to detailed proportions. Measurements were obtained from the plesiotype of *C. excavatus* Gilmore, cat. no. 8676 G. S. C., which I described in Bull. 77, Geological Survey, Canada, pp. 4–11, 1935. The model is one-third natural size. The illustration (fig. *1*) is nearly one-fourth as large as the model.

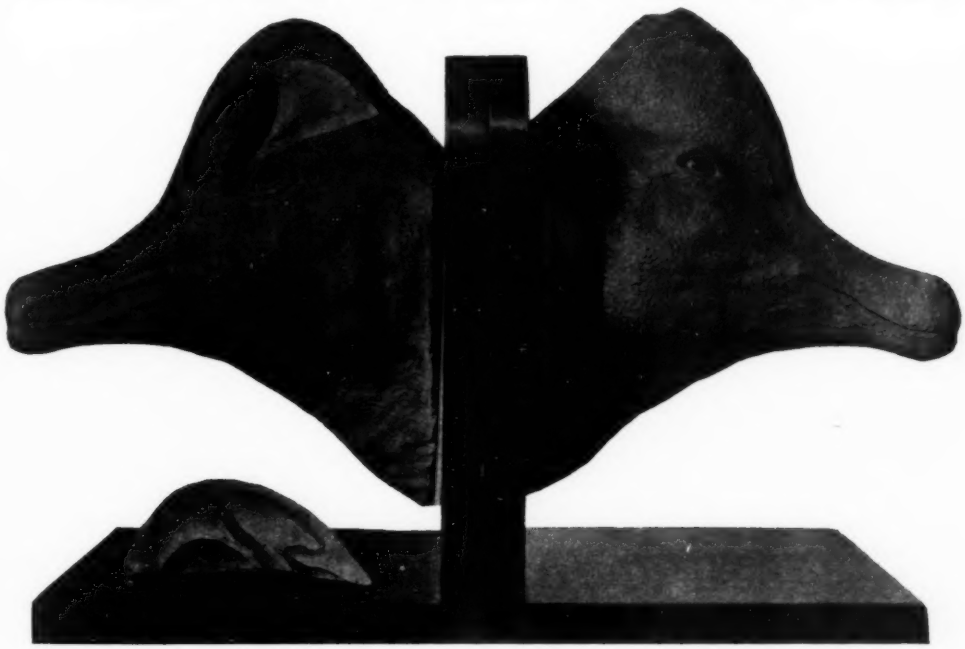

FIG. *1*—Restoration model of *Corythosaurus*. Removable section of hood shows winding narial passages. Modeled by C. M. Sternberg.

The skull was disarticulated before burial and preserved in a sandy clay, and most of the bones were uncrushed. All the rock was removed, and the bones of the head were articulated into an open mount. It was from this skull that details of the modified, enclosed narial passages and subsidiary air pockets were worked out for the genus. The lower jaws were separated from the skull and preserved right side up, thus giving the proper expansion for the back of the jaws. This information can seldom be gained from articulated skulls buried lying on the side. In this specimen the impression of the horny sheath was preserved with the predentary, thus giving the size and shape of the ducklike beak.

The bones of the hood are very thin, and in most articulated skulls postmortem crushing has left the hood flat. Some restorations of *Corythosaurus* show the hood as a thin cockscomblike structure with no space

for the narial tubes or subsidiary air-pockets. My restoration shows a moderately broad truncate beak and bulbous hood. The occipital region is of moderate breadth, but the distal ends of the quadrates are widely separated. Thus the posteroinferior part of the head is much broader than usually shown.

In the evolution of the skull the premaxillae have been extended and folded to enclose the narial passages. As a result of the great expansion of the premaxillae, the nasals have been pushed back and up to form the posterior half of the hood. The narial tubes extend from the external nares back to where the premaxillae divide into lower and upper limbs, and here they run from the lower to the upper limbs through S-shaped tubes and then continue up into the top of the hood. Near the apex of the hood the narial tubes come in contact with the nasal bones. From here they are united in a single tube and surrounded by the modified nasal bones as they turn sharply downward and forward. This tube forms S-shaped and U-shaped air-traps between the external and internal nares. These air-traps would prevent water entering the lungs when the animal was feeding under water. A section of the hood has been cut out of the model to show the winding of the narial tubes and the consequent trapping of air and the subsidiary air pockets which were developed in the sides of the hood and surrounded by the nasals and the lower limbs of the premaxillae. When this section of the hood is removed the internal structure can be illustrated in the classroom or the museum case.

The skin impression is well known in the hadrosaurs, in which the scales on certain parts of the body are about one-third the size of those on the head. In another specimen of *Corythosaurus* well-preserved skin impression was found. A negative mold of an area of the small scales was made in rubber, and with this the scales were pressed onto the clay model. As the model was made one-third natural size it is believed that the integument on our restoration is approximately correct. I believe this is the first miniature model of a dinosaur in which the external covering is an actual cast of known skin impression.

The mouth opens back to about the anterior end of the tooth magazine, thus giving cheek pouches. Such pouches would have been necessary to retain the food as it was being shredded by the teeth. If the mouth slit had extended to the back of the jaws, as is sometimes shown, much of the food would have been lost during mastication. The nostrils are of a type which could be closed when submerged. They lie just behind and above the beak. In Edmonton hooded hadrosaurs the premaxillae completely roof over the narial tubes except at the anterior ends, and it is believed that in all hadrosaurs the external nares were far forward. The size and position of the eye was determined from sclerotic rings, which have been found with several hadrosaur skulls. A glass eye of the proper size was used in the original model to give a smooth surface for casting. The eyelids and the shape and the color of the pupil are hypothetical, but in these details we were guided by the eyes of living reptiles and birds. In *Corythosaurus* the neck was strongly arched, and the head was carried nearly at right angles to the upturn of the neck. In the model, the downward sweep of the front of the neck suggests this development.

The mold was made with rubber modelling compound purchased from the American Anode, Inc., at Akron, Ohio. This proved to be a splendid substance for such use, easily applied, and it gave excellent details. It can be pulled from undercuts, and the surface is not injured by heat generated by plaster while setting. The mould was joined on the midline from the base of the neck to the chin, and this was the only joint and the only part that needed repairing.

When the casts were thoroughly dry they were shellacked and then colored with an air brush. The under coat was green with a second coat of elephant gray and finally a very light coat of rich brown, giving a slightly variegated appearance. Such a color would blend with the jungle in which *Corythosaurus* lived during the late Cretaceous. The eyes were colored by hand, and the eyeballs shellacked to give a sheen.

I am greatly indebted to Mr. C. L. Patch, Chief Taxidermist and Herpitologist of the National Museum of Canada, for helpful criticisms both of modelling and coloring.

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DRY-PEEL TECHNIQUE

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IN THE last few years paleontologists have been using the "peel" technique, borrowed from the paleobotanists, for making sections of fossils. The procedure (Graham, 1933; Darrah, 1936) has been to grind a flat surface in the plane of the desired section, etch this surface for a few seconds with a weak solution of hydrochloric acid, and apply one of several kinds of cellulose solution to the surface. This dries to a thin skin of transparent material, which, when peeled from the specimen, has on its surface a thin film of fossiliferous material. This can be studied either by microscope or by projection. The advantages of this technique lie in the fact that serial sections of a fossil can be made using any desired interval, and these sections can be kept indefinitely for future reference. This method has been used both by workers in vertebrate (Römer, 1937) and invertebrate (Fenton, 1935) paleontology with considerable success, and much information has been gained which otherwise would have been difficult or impossible to obtain.

In an attempt to make peel sections of bryozoans one of the authors (H.F.B.) encountered several difficulties: the suggested materials were not readily available; peels made with a solution of celluloid and acetone had many bubbles; peels took a long time to dry; and it was extremely difficult to remove the peels from very small fossils.

In considering the problem, a variation of the commonly used technique occurred to us, which is new, as far as we know. Its simplicity and speed are remarkable—a completely mounted section can be made in ten minutes—and the necessary materials are easy to obtain. It can be used to best advantage however, only when small sections are desired.

Briefly the method is as follows: the specimen is ground and etched in the usual way; if desirable a stain may be applied to the surface with a camel's-hair brush and allowed to dry; a piece of thin (0.5 mm.), clear celluloid, somewhat longer than the desired section is placed on a smooth hard surface, and an area slightly larger than the section is covered with acetone by means of a medicine dropper; the specimen is then firmly pressed against the celluloid, etched surface down. In two or three minutes the celluloid can be pulled away from the specimen, and one has a perfect, bubble-free section. If it is desired to make a section of a small fossil in a large slab of rock, acetone is put on the fossil and the celluloid pressed firmly against it. In some instances, especially with bryozoans, it has been found that a second or third peel made without intervening etching gives better detail than the first. This is due to the fact that the section is in reality a mold, and the first peel removes any residue that may have been on the etched surface.

These sections may be used and filed without any further treatment, or they may be mounted on glass slides as follows. The celluloid is cut to a desired shape with scissors and placed section side down on a slide; then while it is held firmly in place with the fingers, a fine brush dipped in acetone is run around the edges. Some acetone gets between the celluloid and the glass and dissolves enough celluloid to form a cement, which will bind the section to the slide. In making serial sections of *Thelodus* scales, one of the authors (R.M.S.) found that blocks of wood 1 by $\frac{3}{4}$ by $1\frac{1}{2}$ inches and paper weights could be used to advantage. The celluloid is cut to a rectangular shape slightly larger than 1 by $\frac{3}{4}$ inches, placed on the slide, a block centered over it, and a weight placed on the block. Acetone is applied as above, and the whole can be left while another section is being prepared. If it is desirable that the section itself should not touch the glass, a narrow border

of celluloid may be mounted between the glass and the section-bearing celluloid.

In our opinion the ease and speed of operation, the availability of the necessary materials, and the extremely fine detail obtainable recommend the use of this method for making sections of small fossils.

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ALIGERITES, NEW NAME FOR ALIGER HOWELL, PREOCCUPIED

B. F. HOWELL
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IN A DESCRIPTION of the Middle Cambrian *Centropleura vermontensis* fauna of northwestern Vermont (Howell, 1937), the writer proposed the name *Aliger* for a new genus of trilobites which was required for the reception of a new species in that fauna, *A. venustus*. Dr. J. F. Mason has kindly pointed out that *Aliger* was used in 1931 by J. Thiele as the name for a subgenus of the molluscan genus *Strombus*. The writer therefore proposes the new name *Aligerites* for his Cambrian trilobite, with *Aligerites venustus* (Howell) as the genotype.

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